COMPENSABLE OCCUPATIONAL LUNG DISEASES IN LIVING MINERS AND EX-MINERS IN SOUTH AFRICA, 2003-2013

(The study involves miners in South Africa, and covers all cases certified as compensable)

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DECLARATION

I, Nompumelelo Angeline Ndaba declare that this research report is my own work. It is being submitted for the degree of Master of Medicine in the field of Public Health Medicine (Occupational Medicine), in the University of Witwatersrand, Johannesburg. It has not been submitted for any other degree or examination at this or any other University.

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31st day of March, 2017

DEDICATION

Glory be to God.

My mother

Glory Gelana Ndaba,

my pillar of strength.

My most precious blessings, my little angels,**Eyamazizi and Siba**, for their patience throughout the research process.

ABSTRACT

Introduction: The Occupational Diseases in Mines and Works Act (ODMWA) 1973 (as amended in 2002) provides for compensation of occupational lung diseases in living and deceased miners and ex-miners. Certification data constitute a valuable source of information on occupational diseases in the mining industry.

Objectives: The objectives of the study were: i) To describe the extent and type of compensable lung diseases in South African mining from 2004-2012, by commodity; ii) to describe certification trends over 2004-2012; iii) to examine specific issues related to some of the compensable occupational lung diseases (including service duration in coal miners with coal workers' pneumoconiosis by coal type, describe asbestos related diseases in women and number of miners with exclusive diamond miners certified with mesothelioma during this period); iv) to determine the odds of developing mesothelioma from chrysotile mining and other associated risk factors and v)to determine time from the certification to compensation payment, using a proportion of cases certified in 2009, 2010 and 2011 financial years.

Methods: A descriptive analysis was conducted using the Medical Bureau of Occupational Diseases (MBOD) dataset using claims from living miners, certified from 2004 up to 2012, certified with compensable disease, for the first three objectives. For the fourth objective, the MBOD database was used to select diseases with considerable numbers from the 2009, 2010 and 2011 years. A ten percent sample of each disease group was selected through random sampling using stata 12, to determine time to compensation, joined with Commission for Compensation of Occupational Diseases (CCOD) compensation database. Stataversion 12 was used to clean and analyse data. For the fifth objective, a case control analysis was conducted to estimate the risk of mesothelioma from miners with exclusively chrysotile mining, using exposure data from an external database.

Results: There were67660 compensable disease certifications from 2004 to 2012 financial years, in living current and ex-miners. Almost 62% of the certification outcomes for compensable diseases were from tuberculosis alone, comprising of current, first and second degree TB. First and second degree diseases with no tuberculosis comprised 27% and 1.3% respectively. There were 6601 diseases (9.7%) certified as second-degree with tuberculosis. The proportion of specific diseases other than tuberculosis comprised of silicosis (14%);

silico-tuberculosis (9%);obstructive airways disease (2.2%);coal workers' pneumoconiosis (0.5%); asbestos pleural disease (6.7%) ; asbestos interstitial disease (5.2%); mesothelioma (0.2%); lung cancer (0.04%) and 0.1% were from other diseases.

Females contributed 3.8% to the disease burden while black miners had 92%. Twenty five percent of the compensable diseases were from ex-miners and 49 179from active miners. Although 63% of compensable diseases were from unknown commodity (missing), 30% were from gold mining. The certification trends for pneumoconiosis and tuberculosis peaked in 2008, with statistically significant trend for asbestosis (p=0.01) and silico-TB (P=0.038).

Examination of the specific issues showed no statistically significant difference between CWP certification from anthracite and bituminous coal ranks with regards to service duration, silicosis was certified in 544 platinum miners but none of them had exclusively platinum mining. Asbestos related disease was certified in 2241 women, with 55.4% being pleural disease in the first degree and none of the certified women were younger than 30 years of age, and the average service duration was approximately seven years (mean=6.97 years, SD 6.37 years).

From the sample of 389 certified cases, 26.5% (n=103) were certified at the end of the 2012 financial years. The mean time to compensation 38 months, 36 months and 19.4 months for 2009, 2010 and 2011 financial years respectively.

The case-control analysis found no statistically significant association between chrysotile mining and mesothelioma from univariate analysis (OR=2.0 p>0.05; 95% CI: 0.7-5.4); as well as multivariate analysis (OR=1.5; p>0.05; 95%CI: 0.4-5.2) compared to the reference group.

Conclusion: The burden of occupational lung diseases in living current miners and ex-miners is high, mainly from tuberculosis during this period, irrespective of the commodity and population group. A significant finding from this study was the significant proportion of miners certified with pneumoconiosis with less than fifteen years of mining service. The number of women certified during this period was mainly from asbestos related diseases, a far lesser number of women were certified with disease from other commodities. The findings from this study support what was reported in literature namely; unacceptably long time to compensation; incomplete documentation of exposure history in the form of service records and no established risk for mesothelioma from exclusive chrysotile miners.

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ABBREVIATIONS

ACSOP: Allergy to complex salts of platinum

AMA: American Medical Association

ASBI: Asbestos Interstitial disease, asbestosis

ASBPI: Asbestos Pleural and Interstitial disease

ASBM: Asbestos Mesothelioma

BME: Benefit medical examination

CCOD: Compensation Commissioner for Occupational Diseases

COIDA: Compensation for Occupational Injuries and Diseases Act

ILO: International Labor Organization

MBOD: Medical Bureau for Occupational Diseases

MWC: Mine Workers Compensation

ODMWA: Occupational Diseases in Mines and Works Act

PSS: Progressive systemic sclerosis

NCD: Non- compensable disease

1stD: First degree disease

2nd D: Second degreedisease

TB: Tuberculosis

1stDT: First degree tuberculosis

1stD no T: First degree with no tuberculosis

2nd DT: Second degree tuberculosis

2nd D no T: Second degree with no tuberculosis

CERTIFICATION TERMINOLOGY

Defer	Final assessment on the claim cannot be made, because of poor quality x-rays, no labor history, request for lung function tests, insufficiently completed or incomplete medical reports or details required for compensation.
First (1^{st}) Degree	Cardio-respiratory impairment of more than 10% but less than 40%.
Second (2^{nd}) Degree	Compensable disease with cardio respiratory impairment of more than 40%, or presence of pneumoconiosis and tuberculosis.
TB current or	Active tuberculosis of the cardio-respiratory organs, diagnosed from clinical, radiological and laboratory evidence, and diagnosed during employment in risk work.
TB can antedate	Tuberculosis submitted after employment in risk work, but contracted or diagnosed within 12 months of leaving the mines, or within a year of starting employment. The mineworker is compensated 75% of earnings lost during the course of TB treatment.
TB cannot antedate	Tuberculosis diagnosed less than a year after joining or more than a year after leaving employment in the mining industry.
TB inactive	TB not active
First (1^{st}) Degree TB:	Tuberculosis affecting cardio-respiratory system, with less than 40% impairment but more than 10%, assessed after 12 months of completion of treatment, as evidence by moderate abnormality of lung function.
Second (2^{nd}) Degree TB	Tuberculosis that has resulted in more than 40% impairment as evidenced by severe abnormality of lung function or a combination of tuberculosis with pneumoconiosis assessed after 12 months of completion of treatment.
Defer	final assessment on the case cannot be made, because of incomplete medical reports or details

GLOSSARY

ACSOP	Allergic reaction to complex salts of platinum, including asthma, rhinitis, urticaria and eczema.
Asbestosis	Fibrosis of the lungs due to inhalation of asbestos dust. A form of lung disease (pneumoconiosis) caused by inhaling asbestos resulting in interstitial fibrosis of the lung, varying in extent from minor involvement of the basalareas to extensive scarring.
Benefit medical examination	Medical examination of in-service and former mine workers for certification by MBOD.
Certification Committee	The Medical Certification Committee for Occupational Diseases established under section 39 of ODMWA. This Committee consists of the director and not less than three or more than five other members who are medical practitioners.
COPD	Chronic obstructive pulmonary disease characterized by chronic airflow limitation and a range of pathological changes in the lung, some significant extra-pulmonary effects and important co morbidities which may contribute to the severity of the disease in individual patients.
Coal rank	A classification of coal based on fixed carbon, volatile matter, and heating value of the coal. Coal rank indicates the progressive geological alteration (coalification) from lignite to anthracite.
Controlled mine or works	A mine or works declared as controlled under the repealed Pneumoconiosis Act of 1962 and a mine or works declared as such by the Minister under section 9 of the ODMWA, where it is brought to the attention of the minister that risk work is performed in that mine or works.
Crystalline silica	Silicon dioxide (SiO_2). “Crystalline” refers to the orientation of SiO_2 molecules in a fixed pattern as opposed to a nonperiodic, random molecular arrangement defined as amorphous. The three most common crystalline forms

of free silica encountered in general industry are quartz, tridymite, and cristobalite. The predominant form is quartz.

CWP	Coal workers' pneumoconiosis. Fibrosis of the lungs due to coal dust and silica dust in coal mining work. Structural changes caused by the composite dust, coal and associated coal-mine dust. In workers who are or have been exposed to coal mine dust, diagnosis is based on the radiographic classification of the size, shape, profusion, and extent of parenchymal opacities.
Emphysema	Abnormal, permanent enlargement of air spaces distal to the terminal bronchiole, with destruction of their walls without obvious fibrosis.
International Labour Office (ILO) classification system	A standardized method for describing abnormalities related to the pneumoconioses based substantially on comparison of test with reference radiographs. In the system there are 4 categories of simple pneumoconiosis (categories 0, 1, 2 and 3), with 0 implying no definite abnormality.
Mesothelioma	Cancer of the lining of the lung (pleura) and peritoneum
Non Compensable Disease (NCD):	Disease resulting in less than ten percent cardio-respiratory impairment. The category also includes presence of diseases other than occupational lung diseases.
ODMWA	Occupational Diseases in Mines and Works Act (Act 78 of 1973)
Occupational Lung Disease (OLD)	Respiratory disease acquired from exposure to mineral dust and other hazards in mining.
PMF	Progressive massive fibrosis. Complicated silicosis/CWP characterized by appearance of large fibrotic masses in the lung.Diagnosis is based on determination of the presence of large opacities (1 cm or larger) using radiography or the finding of specific lung pathology on biopsy or autopsy.

Pneumoconiosis	Fibrosis of the lungs due to inhalation of mineral dust.
Pulmonary Tuberculosis (PTB)	Lung disease caused by *Mycobacterium tuberculosis* organisms.
Progressive systemic sclerosis	Disease characterized by thickening of the tissues under the skin, joints, internal organs and involving fibrosis of the lungs.
Quartz	Crystalline silicon dioxide (SiO_2) not chemically combined with other substances and having a distinctive physical structure.
Respirable coal mine dust	That portion of airborne dust in coal mines that is capable of entering the gas-exchange regions of the lungs if inhaled: by convention, a particle-size-selective fraction of the total airborne dust; includes particles with aerodynamic diameters less than approximately 10 µm.
Risk	In relation to a mine or works, means the risk of contracting a compensable disease, to which persons who perform risk work in or at or in connection with that mine or works are exposed.
Risk work	Work performed in or in connection with any mine or works that any person performing that work is exposed to dust, or gases, vapours or chemical substances or factors or working conditions which are harmful or potentially harmful in the opinion of the Minister.
Silicosis	Fibrosis of the lungs due to inhalation of silica dust.
Silico-tuberculosis	Combination of silicosis and tuberculosis of the lungs.

CHAPTER ONE: INTRODUCTION

1. Introduction

1.1 Background

The Occupational Diseases in Mines and Works Act (ODMWA) 1973 (as amended in 1993) provides for compensation of occupational lung diseases in living and deceased miners and ex-miners(1). This Act is administered by the Medical Bureau for Occupational Diseases (MBOD) and the office of the Compensation Commissioner for Occupational Diseases (CCOD) in the Department of Health's Chief Directorate: Occupational Health and Compensation Commission for Occupational Diseases. ODMWA lists the compensable cardio-respiratory diseases under its administration as diseases attributable to performing risk work. The diseases are pneumoconioses, pneumoconioses jointly with tuberculosis, tuberculosis contracted while the person was performing risk work, permanent airway obstruction, any other permanent diseases of the cardio respiratory organs attributable to performance of risk work, progressive systemic sclerosis, and any other disease attributable to risk work as determined by the Minister of Health(1).

The MBOD is responsible for the provision of benefit medical examinations and the certification of compensable occupational diseases through the Certification Committee(1). Claims submitted to the MBOD are for both deceased and living miners and ex-miners. The claims for living current miners are usually submitted for certification from the employers' medical surveillance programmes conducted during employment, and the claims for living former miners are submitted from benefit medical examinations and other medical assessment conducted by attending medical service providers as well as designated centres where this service is offered throughout the country. The Certification Committee determines whether or not there is a compensable disease, the type of disease and extent thereof(1). Certification standards for occupational diseases used by the Committee are based on a code of practice guidelines developed within the MBOD. Compensation is awarded in two degrees, first degree for disease resulting in permanent impairment of more than 10 percent but less than 40 percent, and second degree for permanent impairment of more than 40 percent or simultaneous occurrence of tuberculosis and another compensable condition. Malignant conditions are awarded second degree permanent impairment.

Compensable occupational diseases certified at the MBOD are further managed by the CCOD for claim administrative and financial procedures up to actual payment of compensation.

The certification data and CCOD data constitute a valuable source of information on occupational diseases in the mining industry. Occupational diseases in deceased miners diagnosed at autopsy are published annually in NIOH Pathology Reports available at www.nioh.ac.za. But information on living miners has not been interrogated for over a decade. This study used information captured in the databases to describe the nature, source and extent of compensable occupational diseases in the mining industry. Disease trends over time are examined as a review of the time taken to process claims. Although the ODMWA compensation system and assessment criteria exist for both deceased and living miners, this study focuses on applicable criteria and system components for the living miners (current and ex-miners). Post mortem assessment criteria and processes are therefore not discussed in this study.

1.2 Compensation systems in South Africa

There are two compensation systems for occupational diseases in SA, these are the Compensation for Occupational Injuries and Diseases Act of 1993 (COIDA)(2)and the Occupational Diseases in Mines and Works Act (ODMWA).ODMWA makes provision for benefit medical examinations (BME) for all miners (current and ex-mine-workers) as part of case-finding for mining related cardio- respiratory diseases. The ODMWA compensation process involves determination of the presence of disease and assessment of impairment. This system utilizes a Certification Committee to assess impairment, based on the MBOD code of Practice on medical examinations and standards applicable in the certification of compensable disease. There are broadly a number of certification outcomes namely;NCD, Defer, 1st Degree, 2nd Degree, TB, 1st Degree TB and 2nd Degree TB**(**see Certification terminology on *page xiv***).**

Pulmonary impairment in ODMWA is graded differently compared to COIDA, as summarized in table 1.1 belowand the American Medical Assessment (AMA) guidelines. The COIDA assessment guidelines (3)are based on the AMA guidelines but also include a category for presence of disease with no lung function impairment (no functional impairment). In ODMWA, tuberculosis of the cardio respiratory organs is compensated for loss of earnings, and impairment after 12 months post-completion of treatment. The diagnosis should be based on clinical, radiological and laboratory evidence. However, permanent effects following 12 months post completion of treatment may be evaluated using clinical assessment. Moderate abnormality on lung function impairment is assessed as more than 10% impairment, first degree tuberculosis. Second degree tuberculosis is awarded based on severe lung function abnormality, thus 40% impairment from tuberculosis. Both lung cancer and mesothelioma are assessed as second degree; maximum compensation in the ODMWA system, and 100% impairment in the COIDA system (4,5), once all diagnostic documents and processes have been followed.

In the COIDA system where an employee is assessed to have permanent disablement (PD) of less than or equal to 30%, compensation is through a lump sum payment. The claimant can also apply for upgrade of compensation where the condition progresses and worsens. Where the permanent disablement is more than 30%, compensation is paid out as a pension. In the ODMWA system, both first degree and second degree payments are paid out as lump sums. Claimants certified with first degree in life can, theoretically, continue to work, but for second degree cannot continue to work.

Table 1.1Summary of ODMWA impairment assessment criteria for pneumoconiosis compared with COIDA system, certification of living claims

System	Normal/ functional impairment	Mild impairment	Moderate impairment	Severe impairment*
ODMWA	<10% impairment: FEV1/FVC>75%; FVC ≥80% and FEV1≥80% **No impairment; no compensation**	<10% impairment FEV1/FVC>75%; FVC=79-65% and FEV1=79-65% **No impairment; no compensation**	10-40% impairment* FEV1/FVC=65-55% FVC =52%- <65 and FEV1= 52%- <65 **First degree compensation**	>40% impairment* FEV1/FVC<55%; FVC≤51% and FEV1≤51% **Second degree maximum compensation**
COIDA	<10% impairment: structural impairment with no LFT changes or disease with no symptoms. **Compensation 20% PD**	10-25% impairment of the whole person. ATS: can still do most jobs. **Mild impairment** **Compensation 40% PD**	26-50% impairment. AMA class 3 whole person impairment. ATS: cannot meet demands of many jobs.**Moderate Impairment Compensation 70% PD**	51-100% impairment; AMA class 4 whole person impairment. ATS: cannot do any job. **Severe Impairment Compensation 100% PD**

*In the presence of radiological pneumoconiosis.

1.3 ODMWA Compensation process and system for the living miners

ODMWA cases used for the purposes of this analysis were limited to living cases i.e. alive at submission of claim. Living current miners undergo medical assessment through medical surveillance with respective employers, typically annually, for detection of presence of occupational lung diseases and submission to the Medical Bureau for Occupational Diseases in Johannesburg, if occupational lung disease is suspected or diagnosed. Ex-miners are entitled to two-yearly benefit medical examination at public and other service providers, and have these submitted to the MBOD if an occupational disease is suspected. Ex-miners can also access this service directly from the MBOD and/or public or designated medical assessment centres.

All relevant forms for each case, including supporting documentation (service records, chest-x-rays, lung function tests where available and finger prints) are filed together under a bureau number with each claim for the individual allocated a separate claim number. The Certification Committee decides on each case submitted and a certificate is issued on the decision outcome.

The certification criteria differ according to whether the claim is submitted for a living or deceased claimant. Living current and ex-miners' certification decisions are made based on chest x-ray, reported in line with ILO classification of x-rays, and lung function tests or laboratory diagnosis or confirmation of disease (sputum results, biopsy results, etc), and or histological diagnosis where lung cancer or mesothelioma is diagnosed. Certification for deceased miners is based on post mortem examination of the cardio-respiratory organs and histological assessment; however no reference is made to the lung function tests or radiological findings.

The certification decision is based on the stipulations of the ODMWA, and internal MBOD guidelines, prepared by the Medical Director of the MBOD. The decision is recorded both in the file of the individual case and on the agenda of the meeting. This serves as a paper based backup system. This information is also entered into the MBOD computerised database, the Mineworkers' Compensation System (MWCS). This database generates a certificate for each case, copies of which are sent to the applicant, submitting medical centres as well as to the CCOD.

Certification details for individual cases are accessed from the MBOD database using name, MBOD number and South African national identification number. Annual reports are compiled from this database and data can be exported as a text file, into statistical analysis software. However, the source documents, from the files, can be accessed and retrieved using a Metro-filing system, or certification agenda documents for a specific meeting. The system is mainly paper-based, with some processes computerized.

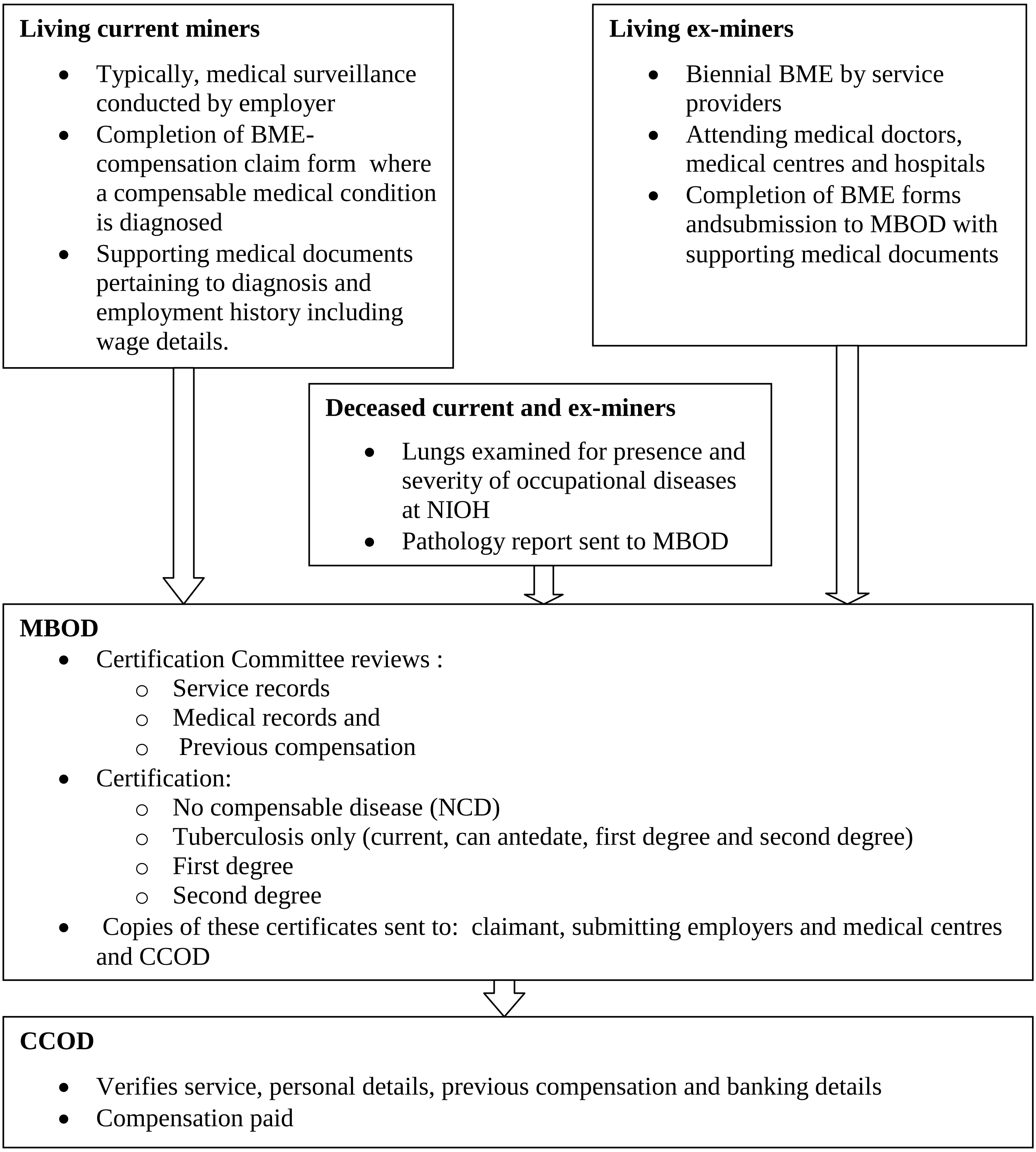


Figure 1.1 Flow diagram showing summary of compensation process for living miners

Description of databases

MBOD Mineworkers' CompensationDatabase

This Mineworkers' Compensation (MWC) database was reconstructed from 2004, and cases submitted before 2004 were captured as pre-2004. The pre-2004 cases were grouped from cases submitted from 1999, 2000, 2001 and 2003; however they do not reflect a complete number of cases submitted and certified during those years. All new applications submitted to the MBOD, after 2004 are recorded electronically into the database.

Information recorded includes identifiers for each claim, demographic details of the claimant, submission date, clinical findings, certification date and outcome of certification. Claims certified before 2004 were labeled as pre-2004 in the database. The Mine Workers' Compensation database was originally designed to accommodate information up to claims payment, from the CCOD. The CCOD database had been compiled separately to the MWC database. It was not complete however, and did not contain all information on files that had been certified. There is no formalized system of status tracking for the processes between certification and payment.

CCOD Database

This database contains CCOD claim registration details, namelyMBOD number, CCOD number, national ID number and names and surnames**.** All other claim details are filed in a paper based system with hardcopy files. Information on claims payment was recorded on claim files, captured on accounting software, Pastel, for each case paid. At the time of conducting the study there was no consolidated payment information, linked to the MWC database, but different spreadsheets were compiled on a monthly basis based on the claims paid.

A new database was compiled in 2014, based on approximately 200 000 CCOD files, to verify which ones had been paid and how much. This CCOD verification database was compiled mainly for payment verification purposes; however there were also details on certification outcome, date, and identification details of the claimant. The number of payments and dates for each payment, verification documents before payment, details of recipient of payments, exposure details, amounts paid and date of certification appeared in the database.

1.4 Literature Review

1.4.1 Occupational Lung Diseases –An International Perspective

Occupational lung diseases are a major public health concern globally, being one of the most frequently occurring, preventable yet most disabling of all categories of occupational diseases (WHO)(6). The World Health Organization listed Occupational lung diseases as one of the occupational health priority area (6). Occupational lung diseases are caused or made worse by exposure to substances in the workplace (7).

Occupational lung disorders are classified into four main groups, based on the biological properties of the inhaled causative agent, namelydisorders caused by exposure to mineral dusts; disorders caused by exposure to gases and fumes; disorders caused by exposure organic dusts; and pulmonary and pleural malignancy including lung cancer and malignant mesothelioma (7).

The International Labor Organization (ILO) prioritized occupational lung diseases, particularly pneumoconiosis, by providing a definition used in most of parts of the world and the development of a classification system of reporting chest radiographs as a means of standardizing classification of these, internationally (8).

Pneumoconiosis is a term used for the diseases associated with inhalation of mineral dusts(7), defined by the ILO as an *"accumulation of dust in the lung and tissue reaction to its presence*"(8). Pneumoconiosis is the most common and most serious occupational lung disease seen in developing countries (6). Industries at risk for the mineral dust diseases include hard rock and other mining, and industries that use silica or process materials containing it(9).

In the South African context, occupational exposure to mineral dust is mainly encountered in the mining and quarrying industry.

1.4.2 Occupational Health Legislation in the South African Mining Industry

South Africa has a dual legislative system for occupational health, one set focusing on all workplaces except mining and another one mainly for the mining industry. The Mine Health and Safety Act, 29 of 1996(10),is aimed at prevention of occupational health related diseases and safety related incidents in the mining industry. Prevention under this legislation includes regulation of the control of occupational health hazards, including amongst others; setting of occupational exposure limits for gasses, chemicals and dusts in the mining industry and periodic medical assessment of current employees to detect early disease as secondary prevention(10). Where prevention efforts fail, as evidenced by development of adverse health effects or; development of occupational diseases, such incidents are reported and a claim submission is initiated with the relevant system. Current and former mine workers are entitled to compensation, where they are diagnosed with diseases affecting the cardio-respiratory organs with an impairment of more than 10%, under the provision of the Occupational Diseases in Mines and Works Act, 1973 as amended(1).

Compensable occupational lung diseases in the ODMWA refer to pneumoconiosis, pneumoconiosis and tuberculosis, tuberculosis alone, chronic obstructive airways diseases and all complex salts of platinum, systemic sclerosis and others.

1.4.3 Occupational Lung Diseases in the South African Mining Industry

South Africa has a challenge of an undocumented burden of occupational respiratory diseases, including asbestos related diseases (11). Reliable data are, however, generated from PATHAUT, a database based on autopsy examination of current and ex-miners, although these are reliable only with regards to deaths in service but poorly representative of deaths in ex-miners.Another challenge is the inability to assess the incidence and prevalence of mining related occupational respiratory diseases (12), in living current and ex-miners.

1.4.3.1 The South African Mining Industry

“Mining is South Africa's largest industry in the primary economic sector, followed by agriculture”(13). South Africa was the world’s biggest producer of gold and is the biggest producer of platinum and one of leading producers of base metals and coal. South Africa’s, diamond industry is the fourth largest in the world. The largest reserves in the world for gold, platinum group metals and manganese ore are in South Africa. The industry was fifth largest in the world in 2012 (14), with the world’s largest mineral endowment (15), with production of 10% of the world’s gold and 40% of the world’s known resources. The largest sectors in this industry in terms of employment, investment and revenue generation are platinum and gold sectors (16). South African mineral reserves include gold, coal, platinum group metals, ferrous minerals, copper, manganese and diamonds (16). Another sector of the mining industry are aggregate and sand producers comprising companies that produce aggregate and sand, operating quarries sand pits and crushing operations. Although gold mining has contributed 40% to the industry employment figures throughout 2004 to 2012, the platinum industry has been the leader in the industry since then.

There were between 450 000 and 520 000 miners employed in the mining sector during the 2004-2012 financial years as shown in Table1.2 below (17). The actual number of ex-miners is not known, but is estimated to be around two million (18). The mining and minerals industry has contributed to the country's economy, industrialization as well as well as playing a major role in infrastructure development (17). This industry has also contributed significantly to the burden of diseases in the country, mainly occupational lung diseases, and to major epidemics in the South African population (19,20).Within the mining industry gold mining has contributed to the burden of disease, as it was previously the commodity with highest employment numbers. There were at least 500 000 miners employed in South African gold mining in the 1990s, approximately 198 000 in 2003 and 142 000 in 2012 (17). The miners employed within the industry, however increased from 2004 to 2012, with the platinum mining numbers increasing and becoming the major contributor, as shown in Table1.2 below.

Table 1.2South African mining contribution to the economy by GDP and direct employees per annum

	2004	2005	2006	2007	2008	2009	2010	2011	2012
GDP*(%)	6.4	6.7	7.5	7.8	8.7	8.2	8.3	8.8	8.3
Employees ('000)	450	440	460	500	520	490	490	510	520
Gold ('000)	180	160	160	169	166	160	157	145	142
Platinum('000)	151	155	169	186	200	184	182	195	198
Coal ('000)	50	57	58	60	65	71	74	79	83
Other('000)	68	71	70	80	87	77	86	95	101

*GDP directly. Source: Chamber Facts and figures 2012(17) Figures rounded off, and expressed in thousands.

Hazardousexposures and health effects

Health hazards in mining associated with occupational lung diseases include crystalline silica, coal dust, asbestos, arsenic, diesel particulate matter, coal tar pitch volatiles, sulphur dioxides, platinum group compounds, and other chemicals used in smelting and hydrometallurgy processes (21). The main determinants for development of occupational lung disease include commodity mined, levels of airborne particles of the hazard, duration of exposure, co-existing illnesses and other lifestyle factors e.g.

smoking, HIV status, etc.(22). Important exposures in mining and related processes associated with occupational lung diseases are not only confined to mineral dust but also exposure to gasses, chemicals and radioactive materials like uranium (23).

Mineral dust exposure that has been associated with diseases includes silica dust, asbestos fibre dust, coal dust, platinum salts, chrome dust and salts, and iron dust. The most common exposure in South African mining, based on employees exposed is silica dust with exposure in gold mining, coal mining, quarries as well as to a lesser extent other commodities. Occupational diseases arising out of and in the course of working in mines range from lung diseases, airways diseases, extra pulmonary diseases and malignancies (19), The prevalence and severity of occupational lung diseases in mining differ with type of mineral dust (22).

1.4.3.2 Diseases Associated with Selected Mineral Dusts in South Africa

The main minerals mined in South Africa for commercial reasons include gold, coal, and platinum group metals and previously asbestos. The occupational lung diseases in mining differ according to mineral exposure and physicochemical properties of minerals mined. Some of the diseases include, from the most prevalent, pulmonary tuberculosis, silico-tuberculosis, pneumoconiosis, asbestos related diseases, COPD, diseases arising from complex salts of platinum and cancers. Thereare many determinants for these lung diseases but cumulative exposure is the most important for some.

Mining and silica dust exposure

Gold mining is the primary industry with occupational exposure to crystalline silica dust, followed by coal mining and other non-mining industries. Silica dust is one of the most important respiratory toxins (24).The Leon Commissionstated in 1995, that exposure in the South African mining industry had not changed but remained the same over the past 50years (25).

The occupational exposure limit for respirable crystalline silica in South African mining industry is $0.1 mg/m^3$(10). This limit is not protective enough to prevent the silica related diseases (26), and has not been lowered despite the country's commitment to reduce the prevalence of silicosis by 2015 and eliminate silicosis by 2030 in workplaces (26).

Occupational exposure to silica dust occurs in a number of industries in South Africa, with mining and related operations being among the problematic of them because of the ore and associated rocks being the source of silica (26,27). The most common exposures to crystalline silica occur in mining and mining related occupations (28), with country rock being the main risk determinant (28), and the minerals mostly associated with exposure are gold, tin, coal, copper, mica, uranium, crocidolite and iron (28). Although all workers in mining are potentially at risk of exposure to silica dust, workers in operations with high exposure and resultant high risk include surface drilling, rock drilling, underground operations, surface milling and dredging (29). Mining activities producing majority of airborne dust include rock blasting, drilling, scraping, barring, lashing, tipping and loading (30).

Within the mining industry, the commodity with highest silica content is the gold, followed by coal (28). Sources of airborne crystalline silica in mining include hard rock mines (platinum and gold), coal mines, surface mines and mineral processing (30).

Chronic exposure to silica dust even in the absence of radiological silicosis can cause chronic obstructive airways disease (24), tuberculosis and extra-pulmonary tuberculosis (31–34). This risk of developing silicosis, and tuberculosis is lifelong, even after exposure ceases (35). Gold miners infected with HIV, with silica dust exposure with or without silicosis have a multiplicative risk of tuberculosis (33).

Health effects of silica dust exposure

Adverse effects of silica dust exposure include silicosis, tuberculosis, chronic obstructive airways disease and airflow limitation, lung cancer and other immunologically mediated conditions such as systemic sclerosis (27).

Tuberculosis

Tuberculosis is a major problem in South Africa, and specifically in the mining industry because of a number of risk factors. Gold miners, because of crystalline silica dust exposure, are occupational category most affected. The risk of tuberculosis in South African gold miners is associated with occupation, age,silicosis status and HIV status (36). Miners with silicosis have up to six times the risk of TB than those without the disease and those with silicosis and positive HIV status have up to 18 times the risk (33).

Table1.3Tuberculosis cases in mining 2004-2012 as reported by industry to DMR

Commodity	2004	2005	2006	2007	2008	2009	2010	2011	2012
Gold	1926	3442	3115	3846	3829	3266	3243	1696	1529
Platinum	745	355	338	358	453	873	993	1005	895
Coal	117	121	88	127	241	207	162	249	212
Diamond	11	30	12	9	8	4	8	6	8
Other	28	67	95	176	150	129	46	106	194
Total	**2827**	**4015**	**3648**	**4516**	**4681**	**4479**	**4452**	**3062**	**2838**

Adapted from Chamber of Mines- Tb in South Africa. Factsheet 2016 (37).

Chronic Obstructive Pulmonary Disease (COPD)

Silica dust exposure is a risk factor for COPD, even in the absence of radiological silicosis (25). In gold miners, COPD is a major cause of disability and increased mortality, especially with combined silica dust exposure and smoking (38).

Other occupational exposures in the mining industry associated with COPD, other than silica dust include coal mine dust, exposure to vapors, gases and fumes as well as occupational exposure to diesel exhaust fumes (39). These exposures occur in mining broadly and not only limited to gold mining.

a) Platinum group metals mining

Most of the platinum group metals in South Africa are mined in the North West Province and Limpopo (17), these include platinum, iridium, palladium, osmium etc. The number of miners employed in platinumsector increased from 91 000 in 1999, 150 000 in 2004, and 198 000 in 2012, in line with the growing demand and market for platinum based products (17). Occupational exposures in this commodity associated with occupational lung diseases have mainly been to platinum salts, occurring at the refining stage, associated with allergic reactions usually due to platinum salt sensitivity.

The literature on respiratory diseases from platinum ore mining is scant. The most commonly encountered respiratory diseases associated with platinum, are mainly from platinum refining. These are a consequence of exposure to platinum salts and sensitization, namely occupational asthma and upper respiratory tract diseases. Not much is known about occupational lung diseases in platinum miners except for low rates of silicosis, reported. However these have also been attributed mainly to miners having worked in another commodity prior to working in platinum mining.

Exposures to dust and ore in the platinum mining sector include platinum, chromium, copper, nickel, iron and palladium(40). However other exposures, similar to underground mining are to non-mineral dust exposures that could be associated with adverse health effects, namely oil mists, diesel emissions and blasting agents(40). Exposure to diesel exhaust fumes, and othervapours, gases, fumes is associated with COPD (39).

Studies conducted in South African platinum mines reported inherent silica content of less than one percent in some platinum mines, and airborne respirable crystalline silica content of 0.2% compared to 9-39% in gold mines (41). Despite the reported low levels of silica dust content in platinum ore, there have been reports of silicosis diagnosed in platinum miners. Although these have been suggested to be probably due to previous employment and exposure in the gold mining sector, it is worth monitoring silica dust levels in platinum mining to exclude the possibility of accidental exposure (42).

A cross sectional study conducted in a large platinum mine , consisting of 969 living active miners found that 23 platinum miners had silicosis or radiological abnormality related to silicosis (2.4%); 15 cases had current TB (1.55%) and 27 cases had COPD (2.8%) (40). However, one autopsy study reported silicosis found in five exclusively platinum miners, and fibrotic nodules in the nodes of twenty five miners. Nelson and Murray (2013) detected silicosis in exclusively platinum miners at autopsy (42). It is therefore likely that occupational exposure to silica dust in gold mining is not always the only explanation for silicosis found in platinum miners, but this would require accurate search and review and documentation of exposure data in various databases where this has been not been routinely reported, including compensation databases.

b) Coal Mining

Exposure to coal mine dust

The South African coal areas are large and mainly situated far from the coast, even the KwaZulu Natal (KZN) coal fields are inland (43). Coal deposits occur throughout the country but mainly in KwaZulu Natal, Mpumalanga, Limpopo and Free State and lesser amounts in the North West Province and Eastern Cape (44). Coal is classified into ranks defined by percentage of fixed carbon by percentage of volatile material and heat content. Coal rank is an indication of maturity, the higher the rank the higher maturity. South African coal is mostly semibutiminous except for a small amount found KZN which is semi-anthracite (45).Semi-anthracite coal in KZN characterizes it as higher in Inherent Respirable Dust Generation Potential (IRDGP) compared to coal in other provinces (Mpumalanga and Limpopo) which have similar IRDGP (45).

Sources of dust generation in coal mines, include cutting, blasting in conventional coal mining, roof drilling can also generate dust (30). Primary dust generation areas not at coal face include conveyor belts, coal haulage transfer points and haulage roads.

The occupational exposure limit for coal dust in South African mining is 2mg/m^{3}irrespective of coal type. However, since coal dust may contain crystalline silica, the limit of 0.1mg/m^{3}for silica dust is used where coal dust contains more than 5% of silica (30).

The rank of coal, determined by percentage content of quartz, and exposure duration longer than ten years have been noted to be the key determinants in the development of pneumoconioses (35,46). However, no South African study has documented the rates of CWP with regards to coal rank.

Coal mine dust exposure, through inhalation in occupational settings has been associated with coal workers' pneumoconiosis, progressive massive fibrosis, chronic bronchitis and chronic airflow limitation as well as emphysema. Recent reports suggest that there is a spectrum of these diseases, referred to as coal mine dust lung diseases (47). The most common diseases within this spectrum are coal workers' pneumoconiosis (CWP) and silicosis. These two have similar radiographic findings characterized by small rounded opacities found in the upper lung zones and usually less 1cm. The more severe form is characterized by coalescence of opacities into large opacities more than 1cm (48). Coal miners with exposure to both crystalline silica and coal dust are at risk of mixed dust pneumoconiosis (49). Recent reports suggest that opacities on chest x-rays of coal miners may not necessarily be small and rounded but can be irregular and can also be distributed equally throughout the lung as a manifestation of Coal mine dust lung disease (CMDLD) (47).

Determinants and burden of CWP

The determinants of the presence of CWP and severity include increasing age, mine size and mining tenure (50). Wang et al, identified some of the determinants of rapid decline of the FEV1 and disease progression to include, work in the roof bolting, lack of respiratory protection, exposure to explosive blasting fumes, use of stored mine water for dust suppression sprays, regional location mainly though mining of thin coal seams with high carbon content and high levels of respirable crystalline silica dust in smaller mines (51).

Reports have suggested that at the current South African OEL of 2mg/m3, miners working for at least 40years have a 12% and 2% probability of developing CWP and PMF respectively (52).

Of the three well known pneumoconioses, coal workers ‘pneumoconiosis (CWP) is the least common in the South African context, with a prevalence of 2-4% and associated with cumulative respiratory dust exposure (46).Neil White (2001) reported that MBOD certification rates had declined from 1980 to 1989, with a rate of 6 per 1000 in coal miners in 1980 to 4/1000 coal miners in 1989 (52). According to the same report, the MBOD 1998/1999 annual report reported that CWP constituted 0,6% of the first degree certifications (approximately 25 cases), no second degree certifications and six cases of CWP and TB combined (52).

c) Asbestos Mining

Asbestos is a name for a group of naturally occurring fibrous, non-metallic mineral rock that splits into fine fibers when processed, also known as fibrous silicates (53) . There are six types of types of fibers that have been commercially exploited and classified into two main groups namely serpentine and amphiboles. The serpentine contains one variety, namely chrysotile and the amphibole have the other five types, anthophyllite, crocidolite, amosite, tremolite and actinolite asbestos.

Asbestos types have several common properties, incombustibility, thermal stability, resistance to biodegradation, chemical inertia towards chemicals and low electrical conductivity (54).

Of the six known types of asbestos, three were mined commercially in South Africa, from the 1800’s, namely; amosite, chrysotile and crocidolite (55). Asbestos mining in South Africa started early in the 19th century with the different types of asbestos foundin different geographic locations and subsequently mined. Asbestos mining in Prieska (Northern Cape) began immediately after discovery of crocidolite fibers in 1803,thereafter chrysotile in the Eastern Transvaal in 1905 (Eastern Transvaal) and amosite in 1907 (Sekhukhune land).Mining peaked in the 1970’s and declined thereafter, with a minimum number of workers being 20 000 employed during the peak around 1977, in the Crocidolite mines (53), and 7317 male employees employed in mines in 1981 (3212 amosite only, 3430 in crocidolite only and 675 exposed to both) (56). South Africa was the main producer (97%) of asbestos in the African continent and produced 97% of crocidolite worldwide and was the only producer of amosite worldwide (57).

The last asbestos mine closed in 2002 (11), and the regulation banning use, production, import and export of asbestos was promulgated in 2008 (58).

Occupational asbestos dust exposure in South African mining occurred mainly through mining and milling, as primary exposure, and also through secondary exposure where workers in various occupations underground were in contact with asbestos material, in mining commodities other than asbestos. Primary asbestos exposure in mining occurred through removal, fragmentation and screening of asbestos ores(59). In the South African context, occupational exposure occurred where family units, women and children were exposed through activities involving removing softer and lighter asbestos from ironstone on site, hammering the asbestos out of the rock known as cobbing (60). Mining of other mineral ores known to be commonly contaminated with asbestos ores, is also a source of occupational exposure, e.g. diamond mining (55).

Secondary exposure occurred in maintenance and construction related occupations, which also exist in mining environments namely, electricians, welders, and other occupations known to be directly exposed to asbestos containing material or in close proximity to operations involving asbestos (59). In South Africa, mining and milling of asbestos resulted in environmental contamination of the mining towns and thus environmental exposure to the communities (61–63).

Health effects

There is no known acceptable level of asbestos dust exposure (59), however the IARC has classified all forms of asbestos to be carcinogenic (64). The three main types of asbestos differ with regards to physical, chemical, bio-persistence in lung tissue and toxicity (65).

Although asbestos is no longer mined in South Africa, asbestos related diseases are still encountered because of their long latency. Asbestos related diseases include benign, non-malignant diseases namely pleural diseases (asbestos pleural fibrosis, rounded atelectasis, pleural effusions and pleural thickening), the more serious asbestosis, and malignant lung diseases (66). The malignant diseases include lung cancer and malignant mesothelioma (pleural and peritoneal), laryngeal cancer and esophageal cancer (66,65).

Determinants of asbestos related diseases in mining

All types of asbestos are known to cause pleural diseases and asbestosis, and have been linked with lung cancer and mesothelioma (52). Health effects may continue to progress even after exposure ceases. The levels of asbestos that lead to lung disease depend on duration of exposure, latency (the earlier on in life the exposure, the higher the risk); cigarette smoking (mainly increases lung cancer risk), fibre type, with amphibole more harmful than chrysotile and fibre size dimensions (66). Asbestosis, a diffuse progressive interstitial fibrosis of the lung, a consequence of exposure to asbestos, is associated with asbestos exposure of more than25 fibre/ml years typically in workplaces (65,67).

Lung cancer and mesothelioma

The association between asbestos exposure and lung cancer and mesothelioma is well established in a number of epidemiological investigations, however there is less extensive epidemiological evidence for other cancer sites (64).

Malignant mesothelioma

Mesothelioma is a malignant tumor arising from mesothelial cells (pleural, peritoneal, pericardial and tunica vaginalis) caused by exposure to asbestos (68). The most common (90%) of these is the pleural mesothelioma (69). It is a rare but fatal tumor, with a latency period of 30 years after initial exposure and median survival time of nine to eighteen months after diagnosis (65,68). The survival time is related to the histological type, the epithelioid type with highest median survival time of 18 months, 11 months for the mixed type and eight months for the sarcomatoid type (65).

The first definitive link of mesothelioma to asbestos was from South Africa, based on this tumor being prevalent in people who worked in crocidolite asbestos mine area (70) and later asbestos inhalation was confirmed as the etiological agent causing mesothelioma (64). The WHO and IARC classified all types of asbestos as carcinogens, class 1- based on sufficient evidence that asbestos causes lung cancer, mesothelioma, pharyngeal, ovarian, and abdominal tumors (64). IARC and WHO confirmed that there is a dose-response relationship between asbestos exposure and mesothelioma and lung cancer, butno lower threshold has been identified (64).

Epidemiology of Malignant Pleural mesothelioma in South Africa

In South Africa, mesothelioma is unequivocally linked with crocidolite asbestos, but uncertainty with chrysotilemining (62).However, IARC classified all six forms of asbestos as carcinogenic, irrespective of where they are found (64).There has been controversy around the risk estimates for chrysotile mining versus crocidolite and amosite (71).Mesothelioma cases associated with chrysotile exposure have been attributed to the contamination of chrysotile by tremolite (72).In the South African context, the mesothelioma risk in mining was much higher with crocidolite or amosite exposure than chrysotile alone (73,74).In one study of living mesothelioma cases, the authors concluded that the few mesothelioma cases linked with amosite fibre and the rarity ofexclusive chrysotile exposed mesothelioma cases linked were consistent with the fibre gradient of mesotheliogenic properties (73).

In another South African study, aimed to determine fibre etiologically linked to mesothelioma in 43 cases, chrysotile fibres were not found alone in any of the mesothelioma cases examined (74). Mesothelioma risk factors with regards to region and mineralogy of the asbestos fibre, especially crocidolite in the Northern Cape, have been discussed in studies (62,73).However, the extent of contribution of chrysotile fibre mined in the former Eastern Transvaal, to the mesothelioma burden has remained controversial. The location of South African diamond mines in relation to asbestos deposits, as well as the nature of Kimberlite has been shown to pose a risk of asbestos exposure to miners (55). However, these two factors alone have not been defined to be sufficient for development of mesothelioma, considering the low dose, and even brief exposure to asbestos associated with this condition (53).The average age of onset is 60 years, which is ten years younger than that of lung cancer (75). There is a strong preponderance in males with a ratio of 2.5:1 (75).

1.4.3.3 The burden of disease in active and ex miners

There is a high prevalence of occupational lung diseases among miners and ex-miners in South Africa and up to a quarter of these are only diagnosed at autopsy (76). Occupational lung diseases in South African miners are a major public health concern, especially in gold miners (19). The most commonly diagnosed diseases at autopsy include silicosis in gold miners, tuberculosis from all mining sectors and chronic obstructive pulmonary disease (COPD) (77). The prevalence of silicosis within different mining industries in 2004 was 22.1% for gold mining, 7.3% coal miners and 4,4% platinum miners

(30). Studies on former miners who had been employed in South African mines, reported a pneumoconiosis prevalence of 26.6% in Botswana former miners (78), and 22% to 36% among ex-miners in the Eastern Cape province in South Africa (79). In a 2008 study on Basotho former gold miners, 50% of the miners examined had at least one potentially occupational respiratory condition and a high prevalence of silicosis (24.6%), tuberculosis (26% past and 6.2% current) and COPD (17.7%) (80). High rates of occupational lung diseases were reported in 1998, from autopsies of currently employed and ex-miners with an 18% autopsy proportion of tuberculosis (PTB), 16% of silicosis and 20% of emphysema (76).

Tuberculosis is a major public health problem, globally with 8.6 million new cases in 2012 (81). Most TB cases and deaths are in men although the burden in women is also high (81). South Africa accounts for a major proportion of the world TB cases. In 2012, the prevalence of TB in South Africa was 458 000 cases, incidence was 530 000 and incidence rate of 948/ 100 000 (18,81). In South Africa, mine workers have a significant contribution into the national burden of disease with an incidence rate of 2500-3000/100 000 in 2013, higher than the general population incidence rate and being the working population with the highest TB incidence in the world (18).

Trends in occupational lung diseases among miners, reported from autopsy data, showed an increase in proportions of miners with silicosis from 1975 to 2007- from 18% to 22% (white gold miners) and 3-32% (black gold miners), asbestos related diseases in diamond mine workers and silicosis in platinum mine workers (82).

There are few published studies on the prevalence of CWP in South Africa. Naidoo *et.al,* (2004) reported pneumoconiosis prevalence of 2%- 4% among living current and ex-miners from three bituminous coal mines in South Africa (46).

The burden of asbestos related diseases in living former asbestos miners

Asbestos mining in South Africa was banned in 2008; but the legacy of asbestos related diseases will still persist for the next decades to come because of the long latency of these diseases (11,62). There is an undocumented burden of asbestos related diseases in South Africa (11), but, as shown below, some data do exist.

In the South African context, the burden of mesothelioma cases from autopsy for the years 2004 to 2007 was 111 comprising 25 mesothelioma cases in 2004; 41 in 2005; 23 in 2006 and 22 cases in 2007 (83). There were 52 asbestosis cases in 2007, out of 64 autopsies on ex-asbestos miners (83).

A survey conducted to assess the extent of disease in asbestos exposed women from occupational mining revealed an extraordinary high burden of occupational lung diseases among this group with 96% asbestosis (n= 741) and 58 of these women had previous TB (7.5%)(84). All of them (n=700) had worked in asbestos mines in the Northern Province of South Africa (84).

White (2001) reported that the numberof asbestos related diseases had been on an increase during the late 1990s, this he reported, was evident from the 1998/1999 MBOD annual report, with asbestosisaccounting for 54% of all first degree certifications and 19.6% second degree notifications (52).

Kisting *et al*, (2000) reviewed medical surveillance records of more than two thousand retrenched workers in crocidolite, amosite and chrysotile mines in South Africa over an eight year period. The prevalence of asbestos-related disease ranged from 21-39% (crocidolite mines); 26-36% (chrysotile mines) and 37% in one amosite mine (85).

Nelson (2012) reported asbestos related diseases in exclusive diamond miners, from autopsies conducted at the National Institute for Occupational Health, between 1975 to 2008 (55). Five hundred and fifty nine deceased mine workers had worked exclusively in diamond mines, and six had asbestos related diseases (four with asbestosis, one with pleural plaques and one with mesothelioma) (55). The extent of asbestos related diseases, especially mesothelioma, in diamond miners is thus of importance.

1.4.3.4Other key aspects of occupational lung diseases in South African mining

A number of studies have confirmed that there is a high prevalence of silicosis among active and former gold miners in South Africa (55,82). Pulmonary tuberculosis has become an epidemic in the mining sector especially gold miners with a high prevalence of latent tuberculosis, multidrug resistant TB rates and high recurrence rates (86). This situation is worsened by other major risk factors for tuberculosis namely silicosis and even silica dust in the absence of silicosis. The high prevalence of HIV among gold miners combined with silicosis, with current silica dust exposure risk, multiplies the risk for tuberculosis by up to 15 times (33).Platinum mine workers may have a risk of silica exposure and eventual development of silicosis (40). Silicosis has been reported in exclusively platinum miners at autopsy (42);however the extent of silicosis has not been quantified in living current and ex-miners having exclusively mined platinum.

In coal mining internationally, the rank of coal, determined by percentage content of quartz, and exposure duration longer than 10 years have been noted to be the key determinants in development of pneumoconioses (45). It is necessary to understand the extent to which the difference in mineralogy and coal type could be associated with coal worker's pneumoconioses in South Africa.

1.4.4 Time to compensation

The mineworkers compensation system has been reported to be unknown to former mine workers, thus not fully accessed and utilized by ex-mineworkers (87). The usual reported time for a compensation claim to go through the system is two to three years (88). Less than 17% of the claims submitted in 2009 were processed in that year and seven percent of claims submitted in 2006 were resolved. Murray et al. (2002) found that 11% (n=31) of cases certified with first and second degree were paid by February 2001 and had undergone autopsy during the 1999 calendar year (89). Studies conducted in living active and ex-mine workers, reported delays following claim submission, with a small proportion receiving compensation. Steen *at.al*, (1997) reported that very few of the former mine workers with occupational lung diseases in Thamaga, Lesotho had been compensated (78). In another study of former ex-mine workers, 2.5% had been fully compensated and 62% had not been compensated. In a study conducted from an occupational medicine clinic in Cape Town on former mine workers, 20% of 84 former mine workers with silicosis received compensation, with a median time of 51 months ranging from 22 to 84months (90). Claims management has been of concern within ODMWA compensation system, and delays have been reported.

Summary of literature review

There is a high burden of occupational lung diseases arising from the mining industry; however disease rates and trends have been estimated from autopsy studies and cross sectional surveys mainly. The last published MBOD annual report was in 2000. However a number of other issues are worth reviewing from then, to update the body of knowledge on the status of diseases in current and ex-miners.

Problem statement and justification for the study

In the SA context, the extent of occupational lung disease in gold miners, following introduction of antiretroviral treatment in 2002, intensified TB management programmes and other socioeconomic conditions, has not been assessed. The trends of pneumoconiosis in living current and former miners have not been updated since the last published MBOD report in 2000.

Some of the issues requiring attention in occupational health from the studies and body of knowledge on occupational diseases in mining includeascertainmentof the extent of silicosis certified in life in exclusively platinum current and ex-miners, and the burden of disease in coal miners and whether the same determinants are applicable in the South African sector with regards to exposure duration and different coal ranks found in different regions/geographic areas.

Although asbestos is no longer mined in South Africa, the burden of asbestos related diseases has not been interrogated recently. The specific issues include disease types and extent in women who were previously occupationally exposed, and, given discussion on mesothelioma and fiber type, the extent of mesothelioma risk from exclusively chrysotile asbestos mining. Asbestos fibers have been identified in lungs of diamond miners at autopsy; however no mesothelioma has been reported in exclusively diamond miners during life.

Finally, within the South African context, the current compensation challenges and proposed reforms, it would be of benefit to understand the if any of there are any delays internally within the compensation process, as a baseline timeframe to improve from

Aim of the study

This study looks at the burden and trends of occupational lung diseases using compensation disease certifications. It also examines the efficiency of the delivery of compensation and the contribution of chrysotile exposure to the likelihood of developing mesothelioma.

Study objectives

Objective1: To describe the extent and type of compensable lung diseases in South African mining, 2004-2012, by commodity.

1.1 To describe the type and number of compensable occupational lung diseases certified by year from 2004 to 2012.

1.2 To describe the certified compensable occupational diseases by age, sex, race, commodity and service duration.

Objective 2: To describe certification trends over 2004-2012.

2.1 To examine certification trends over 2004-2012 for the pneumoconiosis and tuberculosis by commodity mined.

2.2 To determine trends in silicosis certifications in platinum miners over 2004- 2012.

Objective 3:To examine specific issues related to some of the lung diseases certified for compensation

3.1 To evaluate the duration of service in miners with coal workers' pneumoconiosis by coal type mined, anthracite vs. bituminous.

3.2 To describe asbestos related diseases in women.

3.3 To determine the number of miners with exclusive diamond mining who have been certified with mesothelioma, 2004-2012.

Objective 4: To determine time from the certification to compensation payment

5.1 To calculate the proportion of cases whose compensation was paid out following certification for the 2009, 2010 and 2011 financial years.

Objective5: To determine the odds of developing mesothelioma from chrysotile mining, and associated risk factors.

CHAPTER TWO: METHODS AND MATERIALS

This chapter will look at methods and materials used for the five study objectives, in sequence. The methods for each objective will be presented in order.

2.1 Study Design

This study was mainly a descriptive study involving quantitative methods. The study involved secondary data analysis of certification data recorded in the MBOD certification database and service records of the claims that underwent certification; and payment data recorded from the CCOD files, recaptured and verified in March 2015.

The fifth objective of the study used a case-control analysis to determine the odds of developing mesothelioma from exposure to mining chrysotile asbestos, and other associated factors.

2.2 Study Population

The study population consisted of all miners and ex-miners who were alive during claim submission and were certified from 2004 to 2012 financial years, excluding post mortem claims.

For the first, second and third objectives, certification data recorded in the MBOD database from 2004 up to 2013 was used to extract details of claims certified between the 2004 financial year up to the 2012 financial year, ending March 2013. Compensable diseases were extracted for this period, and restricted to claims that were submitted from miners and ex-miners who were alive at the time of claim submission. No sampling was done for these first three objectives, as they were mainly descriptions of the findings from certification. Only disease claims with vital status confirmed as alive, certified with compensable lung diseases from 2004 financial year to 2012 financial year, were included in the final analysis, as shown in Figure 3.1.

2.3 Sources of Information

The Mineworkers' Compensation (MWC) database was used for both the descriptive subsection and the case control study. Data for the period 2004 to 2012 were extracted for analysis. Claims certified before 2004 were labeled as pre-2004 in the database and were not utilized for analysis. The CCOD database had been compiled separately to the MWC database. It was not complete, however and did not contain all information on files that had been certified. Post mortem claims were excluded from this analysis

CCOD Database

The CCOD database contains claim registration details, namelyMBOD number, CCOD number, national ID number and names and surnames**.** At the time of conducting the study there was no consolidated payment information, linked to the MWC database, but different spreadsheets were compiled on a monthly basis based on the claims paid. A new database was compiled in 2014, based on approximately 200 000 CCOD files, to verify payment status and amounts paid. This CCOD verification database was compiled mainly for payment verification purposes, however, there were also details on certification outcome, date of certification, identification details of the claimant, payment episodes and dates for each payment, verification documents before payment, exposure details and amounts paid.

Other sources of information

Information on exposure details, employment duration, and occupation and risk classification were sourced from a separate spreadsheet named service records dataset. This spreadsheet had been compiled using the MBOD files, to document all information on each claimant based on the file information. The unique identifiers were claim number, file number and Bureau number. However each Bureau number could be linked to a number of file numbers where different files were compiled for each individual and a file could also have several claim numbers. For this reason, several identification numbers were used in some instances to link different sources of information.

2.4 List of Variables Used

Case ID: Identification of each individual case, claimant using the national identification number

Bureau Number: Number allocated at the MBOD to register a miner

Claim type: Vital status of the claimant at the time of claim submission, whether alive or dead (living, dead with organs, dead with no organs.)

Claim status: Employment status of the claimant at the time of claim submission (current and ex-miner)

Claim ID: Identification number for each specific claim made by an individual, with the same Bureau number

Claim date: Date on which the claim was lodged with the MBOD

Finding date: Date on which certification stipulated the finding

Claim age: Age of the claimant at the time of claim submission

Finding year: Year during which certification decision and finding stated

Mine max service: Mine at which maximum duration of service was held

Mine last worked: Mine where last service was held before or at the time of claim submission

Mine type: Commodity mined in that mine

Finding type: NCD, 1st degree Disease, 2nd degree Disease, TB, 1st D T, 2nd D T.

2.5 Descriptive Study

The descriptive study used absolute numbers as no meaningful denominators were available. Given the long latency of occupational diseases, and the lag between exposure and development of disease, it would not be appropriate to use the numbers employed in mining at the time of diagnosis asa denominator. It was also taken into consideration that different occupational diseases have different latency periods. The study focuses on both current and ex-miners, no accurate denominator could be used for both as some diseases are likely to develop later in life, after employment, and therefore would be more likely to be found among the ex-miners.

Exposure details

Exposure was described based on several variables,namely mine last worked in or worked in at the time of claim submission, and mine where maximum service was recorded. This was used to assign thecommodity that could be associated with the outcome, where this could be meaningfully done. However, this information was not very accurate with regards to service duration and onset of exposure for the specific commodity to which exposure could be attributed. Depending on the specific objective, where specifics were required for exposure ascertainment, the service records dataset was used to further define exposure with respect to all mines worked in, and the mine names. The service records details were required for coal type assignment based on mine name and geographic location, e.g. or coal workers' pneumoconiosis (CWP), for ascertainment of exclusively platinum or diamond mining and, for asbestos related diseases in definition of fiber type. From the service records the mine name was used to search other sources of information specific to the mine geographic location, using relevant literature on mineralogy defined for that area, and eventually assignment of the appropriate mineralogical type.

2.6 Statistical Analysis

Data provided in the excel spreadsheet extracted from the MWC database were exported to Statistical software version 12 for analysis. Personal identifiers were removed from the datasets, except for unique identifiers namely Bureau number, claim number and Claim ID which were necessary to link with other datasets for further analysis. Although the Bureau number is unique to each individual, this could not be used on its own because an individual can claim more than once, according to occupational disease presentation or following submission of BME, or where clinical assessment shows evidence of clinical deterioration.

Exploratory data analysis was conducted, and data were cleaned for duplicates and completeness of data within specific variables. To increase meaningfulness, data were cleaned in line with clinical interpretation and certification guidelines of specific conditions e.g. mesothelioma are all compensated as second degree, etc.

2.6.1 Determination of the final sample used for analysis

The mineworkers' database was used to extract MBOD certification data of cases certified from 2004 to 2012. Due to incompleteness of data for the other years before 2003 and 2013 financial year, these were excluded from analysis. Deferred cases and all other categories of non-compensable diseases were excluded from further analysis, as well as cases that were dead at the time of claim submission. Figure 3.1 below provides a methodical process flow on how the final the sample for analysis was derived.

2.6.2 The nature and extent occupational diseases

The MBOD dataset was used for this objective. Data cleaning was conducted including identification of missing variables, outliers and duplicates. Certification data were utilized, which has outcome details categorized according to certification outcomes into 27 categories.

Five of the categories were excluded from final analysis as they imply non compensable disease. These are: Non compensable disease (NCD); TB cannot antedate (TB cannot); TB as before; TB not compensable and deferred.

The outcome variables used for description were the certification year, the certification outcomes in the form of findings (1st D no T, 2nd D no T, 2nd D and T, Tb, 1st D T and 2nd D T); as well the specific disease found. A new category was formed for better categorization of information, using the certification finding and disease found to define a new Disease Degree Specific (DDspec), e.g.where there was 2nd Degree no T, and the disease was OAD, then in DDspec this would be coded as OAD2. This was for ease of analysis, to use one variable instead of two.

Compensable occupational lung diseases in living current and ex-miners from 2004 to 2012

Current and ex-miners certified from pre 2003- 2013FY (n=176 343)

Exclude Pre 2004 certifications (3464) & 2013 FY (302) **Total: 3766**

Current and ex-miners certified from 2004- 2012 financial years (n=172577)

Exclude defer (4051), refer to joint committee (223), certification amend (3), certification decision corrected –No (2) **Total: 4279**

Certified occupational lung diseases in current and ex-miners 2004-2012 financial years (n=168298)

Exclude NCDs (52651), remove T cannot antedate (5224), T as before (6971), T not attributed to mining service (205), T not attributed to risk service (251). **Total: 65 302**

Compensable occupational lung diseases in current and ex-miners from 2004-2012 financial years (n=102996)

Exclude deceased (20566) & deceased with no organ (854). **Total: 21 420**

Compensable occupational lung diseases in living current and ex-miners from 2004-2012 financial years (n=81576)

Exclude deceased (**33**) & worker status unknown (1866). **Total: 1899**

Living current and ex-miners certified with compensable occupational lungs disease, 2004-2012 financial years (n=79 677). Final sample size= 67 660*

FY= financial year. * Excludes cases certified with compensable disease but no certification finding or disease stated.

Figure 2.1 An illustration of determination of final sample used for analysis

2.6.3 Certification trends over 2004-2012 for the pneumoconioses and tuberculosis by commodity mined

Pneumoconioses and tuberculosis certifications were examined using the financial year during which they were certified, together with the commodity where maximum time was worked in service. There trends were displayed graphically for 2004-2012 and tested for significant trend for all the pneumoconiosis (asbestos interstitial disease, coal workers'pneumoconiosis and silicosis) and tuberculosis by the np-trend command using Stata12.

2.6.4 Examination of specific issues related to some of the pneumoconioses certified for compensation

To evaluate the amount of silicosis certified in platinum workers, the certification finding of silicosis was extracted from a set, and from this set, those whose maximum service was held in a platinum mine were selected. The cases were described with regards to demographic and exposure details. These cases were then set into a separate dataset of silicosis in platinum miners. This dataset was joined with the service records dataset using identifiers in the form of claim number and Bureau number as unique identifiers. All service records were linked to respective claim number and Bureau number. The cases were then limited to those with exclusively platinum mining service. The cases with exclusively platinum mining service were identified and described accordingly.

Coal workers' pneumoconiosis certified from 2004 to 2012 financial years was extracted from the database and stratified according to coal type. The coal type mined was derived from mine name and region where the mine is based, and a database from the Department of Mineral Resources of all the coal mines in South Africa as at 2004 was used to locate these mines (summarized in Appendix six). The database also provides details of the coal types mined, whether anthracite or bituminous.

The asbestos related diseases were analyzed to describe the women who were certified with asbestos related diseases and to determine if any of the mesothelioma cases had exclusively diamond mining, as exposure.

For the women with asbestos related diseases, women were extracted with asbestos related diseases from the main dataset, for the period of analysis. The dataset was restricted to women, as described in the dataset under gender. The number of women with asbestos related diseases was determined together with their average service duration, nature of disease and severity, age groups and commodity with maximum service. Furthermore the mesothelioma per year, were stratified according to fiber type (asbestos fiber mined at the commodity where maximum service period was held). This was then used to compute the ratio for the three fiber types predominantly mined in South Africa, namely crocidolite, amosite and chrysotile. Determination of fiber type for each mine was sourced from joining the dataset of certified cases with asbestos related diseases to the service records dataset, which provided the mine name. The mine name was then coded according to fiber type. As described under the case control study.

Mesothelioma cases were extracted from the asbestos related diseases and used to verify the mine where maximum service was held and those extracted to further analyze if any of these had exclusively diamond mining. The mining details and exclusive diamond mining were sourced from the service record and limited to those with maximum mining service in diamond mines to eventually define those with exclusively diamond mining.

2.6.5 Time to compensation

The entire population was the total number of compensable diseases certified with compensable occupational lung diseases from 2004 to 2012, being 67 660 diseases. This population was too large to study, given the period under study and recent years being of relevance to the study; theyears 2009, 2010 and 2011 were selected to provide contemporary information. However, the 2012 year was not used as this was likely to have most claims being in the process of being handled before compensation. This was based on documented estimates of time to compensation being 18 months to 51 months (90)from the time of submission. Within each one of the three selected years from which sampling was to be conducted, a sampling frame of the disease groups was listed and ranked with no labels, assigned rank number. It was decided that pleural disease, pneumoconiosisand mesothelioma were appropriate to be selected, as they were well represented in all three years in numbers for the years to be selected.

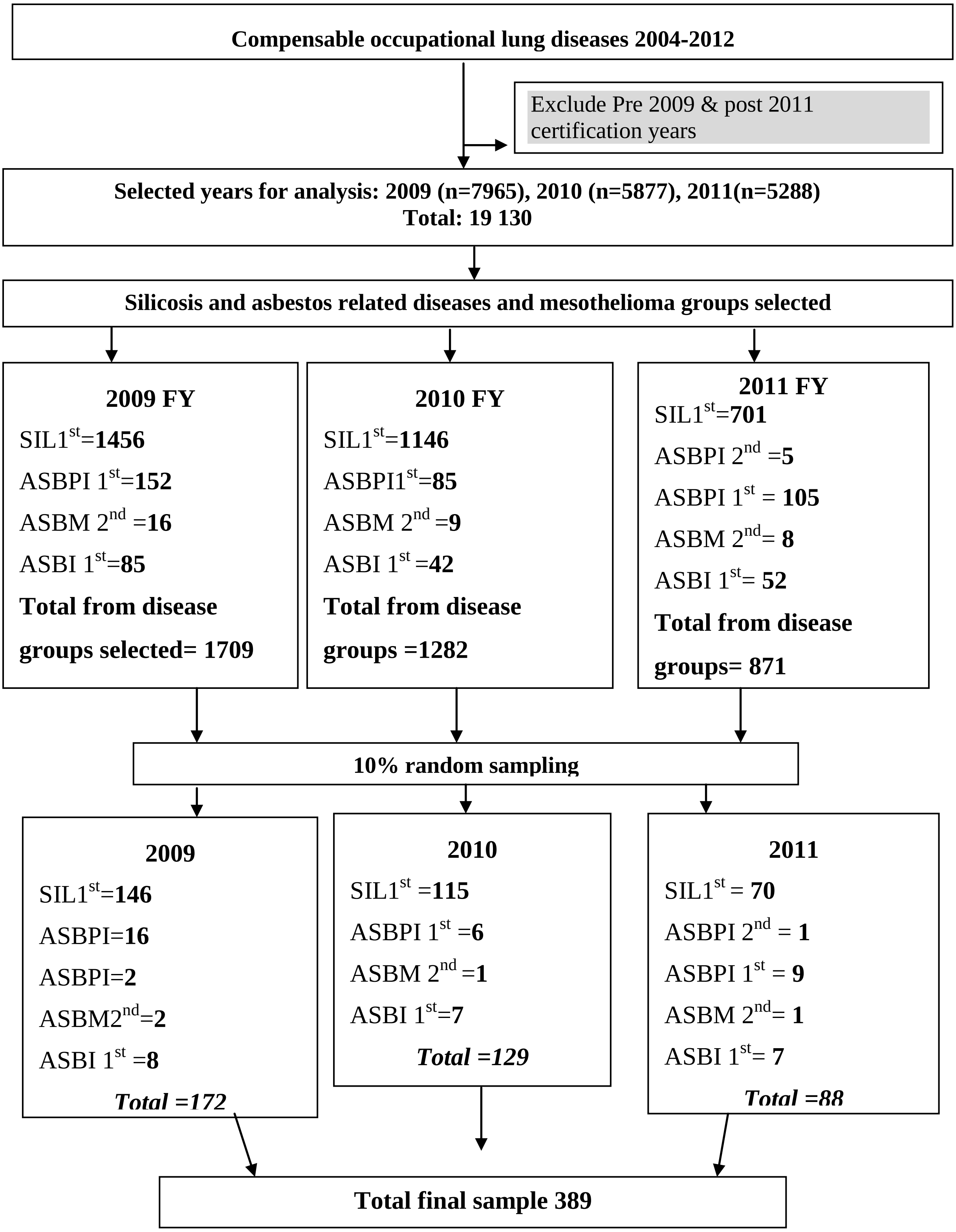
Disease groups with considerable numbers were selected, namely asbestos pleural, asbestos interstitial diseases and silicosis. The CWPN group was not selected. Malignant diseasesare automatically second degree and are well specified upfront for certification; thus the same information is used for assignment of compensation status, and ease of eventual compensation. The malignant diseaseswere represented by the mesothelioma certifications.

A ten percent sample of the each disease group was selected through random sampling (Statistical software version 12) to get to the final number of all diseases within each certification year to be followed up, to be used for calculation of time to compensation. Ten percent was deemed sufficient and representative of the entire population of claims certified with compensable diseases.

Data analysis for time to compensation

The main data set was used to extract three subsets, for the years 2009, 2010 and 2011. The 2009 subset was extracted by initially tabulating data according to finding year and keeping those with 2009 as finding year to make the 2009 subset called "sampledata2009". From this dataset, the disease groups were verified and those representing selected pneumoconiosis and cancers were selected as asbestosis related diseases (both pleural and interstitial diseases), mesothelioma and silicosis disease groups. For this analysis and sampling purposes both pleural and interstitial asbestos were considered to be asbestosis although these are clinically distinct groups, but for compensation purposes these are essentially considered the same.

The dataset consisting of a sample of 189 cases was merged with CCOD payment dataset, last verified in March 2015, using a unique identifier and Bureau number. A new dataset with certification and payment data for the 189 sample was compiled on an excel spreadsheet. Data were imported into Stata version 12 and analyzed. The number of compensated cases was calculated; using certification date and payment date, and the difference between the two dates was calculated, in months. The proportions of compensated cases were determined and further defined by year of certification, diagnosis at certification and proportions paid per payment year.



FY=Financial year. SIL=Silicosis. ASBI=Asbestos interstitial disease. ASBM=Asbestos Mesothelioma ASBPI=Asbestos pleural and interstitial disease.

Figure 2.2 Selection of final sample used for analysis of time to compensation

2.6.6 Case control analysis to determine the odds of mesothelioma from chrysotile mining, and associated risk factors

A case control analysis was conducted to determine risk factors for the development of mesothelioma in miners and ex-miners in chrysotile mining. A dataset of mesothelioma cases who had been certified with compensable disease was extracted from the MWC. Cases used for the purposes of this analysis were limited to living cases i.e. alive at submission of claim. This was because exposure details were more complete from these claimants, compared to claims submitted on behalf of the ex-miners and miners who were not alive at the time of submission. Controls were sourced from MWC database, certified with non-compensable disease (NCDs), certified from the 2004 to 2012 financial years.

None of the cases were younger than 40years of age, thus the controls were restricted to a minimum 40 years.

a) Selection of cases and controls

There were initially 145 mesothelioma cases, and five controls were selected for each (1:5 ratio). The number of controls selected was therefore 725. The controls were selected randomly using Stata version 12 software. The cases and controls are described below.

b) Description of cases

Alive at the time of claim submission

Certified with mesothelioma by the Certification Committee

Certified between 2004 financial year to 2012 financial year

Minimum age at certification being 40years

c) Description of controls

Certified between 2004 financial year to 2012 financial year

Living at the time of claim submission

Certified with Non-compensable disease

Minimum age of 40years

d) Exposure classification for case control analysis

Age

Age captured in the database is in the form of a continuous variable, as age at the time of claim submission. A new categorical variable was generated for age group (AgeGP), calculated as a difference between the date of birth to finding date, and categorized into ten year intervals. The age categories within this variable were, 40- <50years; 50-<60years; 60-<70years and 70 years and above.

Fiber type

To determine exposure classification, the final set of cases and controls was used and joined with the service records dataset. The service records dataset was a dataset compiled from service records per claimant. Each service record was captured per specific mine worked with relevant starting and ending date for service in that mine, as well as duration estimation.

The dataset of 878 cases and controls was joined with service records using claim ID and Bureau number. A total number of 1500 cases and controls together, was a result of the joining, as there was duplication according to the number of individual service records available pre case/control claim identification. The dataset was edited such that each case/control was linked to the mine name where maximum service was held, using the service duration and dates to confirm maximum service at each mine. The duplicates per claim ID that were not linked with maximum service were dropped and not included for final analysis. A total of 878 (145 cases and 733 controls) were used for determination of fiber type, four controls and one case had been duplicated. Where the mine type with maximum duration was not asbestos mine, a common designation of "no asbestos" was used, because of the nature of the database, only maximum mine is recorded for exposure. Where the maximum service duration was held in the asbestos mine, the mine name was sourced from the service records dataset.

Several resources including an MBOD database of controlled mines (still under construction), literature on mineralogy and geographic location of asbestos mines (62) and manual search of the geographic location of that mine were used. Asbestos fiber type was allocated according to the mine with maximum service, using the geographic location of the mine to classify fiber type according to the type predominantly occurring in that area. The fiber type was coded using the geographic location of the asbestos mine, based on literature available on mineralogy of the asbestos type found in a geographic area(62). Asbestos fiber types used for coding were thus

1) No Asbestos: non-asbestos mine

2) Chrysotile asbestos for mines that were in the Eastern Transvaal, currently known as Mpumalanga province along the KwaZulu Natal border;
3) Amosite asbestos for mines that were in the Northern Transvaal area, specifically the Penge area as these were predominantly, amosite(91). Literature was consulted to verify amosite mines in the Penge area namely, Penge group of mines (Penge, Weltervred and Krommellenboog); Cape asbestos (Cape plc) operation Malipsdrift (Egnep) and Dublin Consolidated mines.
4) Cape crocidolite asbestos for mines that were in the Northern Cape area, including Kuruman, etc.
5) Amosite and crocidolite asbestos for mines that were in the Northern Transvaal area, as there was mixture of both amosite and crocidolite asbestos types of varying degrees/ proportion
6) Unknown asbestos fiber for mines that were captured on the database as asbestos mine but name unknown or captured as "*unknown asbestos mine*".

The asbestos fiber category was therefore categorized into six ordinal categories, the ordering of the categories was based on the mesotheliogenic properties of asbestos fiber type, namely Crocidolite>Amosite>chrysotile(62,73). No asbestos mine=0, chrysotile asbestos=1; Amosite=2; Cape Crocidolite=3; Amosite and Crocidolite mixed=4 and unknown asbestos =5.The reference category was "No asbestos mine" (asbestos=0).

The final conversion guide for using mine name can be found in Appendices seven and eight.

Duration of service

Duration of service for both cases and controls was extracted from the service at the maximum mine worked. Service duration was captured in months originally in the database. This was manually converted to duration of service in years (divided by twelve) and categories into seven categories namely 0-4 years, 5-9 years, 10-14 years, 15-19 years, 20-24years,25-29years and 30 years and more (30+). The reference category was 0-4years.

Population group and Race

Population group was captured on the dataset as a "string" variable. A new nominal variable was created, race, encoded from population group. The race categories were: Asian=1, black=2, coloured=3, white=4 and unknown/missing race=5, based on the standard race classification in South Africa. The reference race for analysis was Asian (race=1) as they were least in numbers.

Sex

The number of women was generally below 5% of the total compensable occupational lung diseases. However a decision was taken to include women in the final case control analysis, considering the significance of women in asbestos exposure historically and epidemiologically in asbestos related diseases in South Africa(84). It was therefore epidemiologically important to determine if sex was a significant risk factor for development of malignant mesothelioma. Women (sex=0) were used as a reference group for regression analysis as they were fewer than men (sex=1).

Latency

Service records were used to identify the onset date, as the date of first employment in the first mine employed at. For the cases, the onset date of employment at the first asbestos mine worked at was used to calculate latency.

Univariate and multivariate analysis

A separate set of a cases and controls dataset was compiled and described according to demographic and exposure characteristics. Continuous variables were coded and categorised for ease of stratification of risk factors. Univariate analysis was conducted on the demographic (age-continuous variable and age group-categorical variable), sex and exposure details, namely service duration, fiber type, population group and latency. This was conducted to determine if any of the independent variables were risk factors for mesothelioma. Multivariate regression analysis was conducted based on significant risk factors determined from univariate analysis, controlling for known risk factors that could also be effect modifier, namely age and sex.

Multivariate logistic regression models were fitted to determine demographic and occupational exposure factors associated with mesothelioma in general initiallyand, mesothelioma from occupational exposure to chrysotile asbestos fiber. The final model was determined using risk factors that together produced a better fitting model. This was initially conducted for the outcome variable being mesothelioma (1= cases, 0=controls) and the fiber types stratified as per fiber type categories. The second aspect of analysis included using only chrysotile (fiber type=1) and other fiber types combined into one category (as zero, fibre type=0). Possible predictors included age, sex, and duration of service in asbestos mine, latency and fiber type in the mine with maximum service duration.

Ethical and Legal Considerations

Research approval was granted by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand. Permission was granted by the Compensation Commissioner to access data from the MBOD and CCOD datasets for analysis for this research project (Appendix 2). Clearance was given for research involving secondary analysis of a database (Ethics clearance number: **M130931**; Appendix 3).

CHAPTER THREE: RESULTS

3.1 Compensable occupational lung diseases

There were a total number of 67 660 compensable occupational lung diseases certified in current miners and ex-miners in South Africa between 2004 and 2012 financial years. The demographic and exposure characteristics of the miners and ex-miners certified with compensable diseases during this time are described in table 3.1 below.

Almost 62% (n=41 956) of the certification outcomes for compensable diseases were from tuberculosis alone, comprised of current, reactive, TB that could antedate, first and second degree TB, as shown in table 4.2. Three thousand eight hundred and seventy eight cases, six percent, had compensable disease after twelve months of completion of TB treatment in the form of first-degree (n=2350; 3.5%) and second degree tuberculosis (n=1528; 2.3%). Twenty seven percent (n=18342) of the compensable diseases were first-degree diseases with no tuberculosis and 856 (1.3%) were second degree diseases with no tuberculosis. Six thousand, six hundred and one diseases (9.7%) were certified to have concurrent tuberculosis, thus second-degree certification: second-degree with tuberculosis.

The specificoccupational diseases as per diagnosis certified during the period under study are shown in table 4.3. Tuberculosis comprised 61, 9% (n=41 808) of the diseases followed by silicosis (n=9894; 14.6%) and silico-tuberculosis (n=5866; 8.7%). Malignant diseases comprised approximately 0.3 % (n=173) of the total certified compensable diseases.

The number of total claims submitted per year, for the period under review is shown in Appendix Ten, with status of claimant at the time of submission. The number of certifications per financial year, against the total claims and certification outcomes is shown in Appendix Eleven.

Table 3.1 Demographic and exposure characteristics of cases certified with compensable occupational diseases 2004-2012

Characteristic	**Category**	**Number (%)**
Age (n= 67 660)	<30	1777 (2.6)
	30-39	9857 (14.6)
	40-49	24754 (36.6)
	50-59	19065 (28.2)
	60-69	5368 (7.9)
	70+	6846 (10.1)
Employment status	Current miner	49 179 (72.8)
	Ex-miner	16 805 (24.9)
	Missing	1676 (2.5)
Sex (n=67 660)	Male	63 810 (94.3)
	Female	2 553 (3.8)
	Missing	1297 (1.9)
Population group (n=67 618)	Black	62 341 (92.1)
	White	1 267 (1.9)
	Coloured	91 (0.1)
	Other	60 (0.1)
	Missing	3 919 (5.8)
Mine commodity (with maximal employment) (n=67 600)	Gold	20 522 (30.3)
	Coal	725 (1.1)
	Platinum	3 338 (4.9)
	Iron	15 (0.02)
	Manganese	24 (0.04)
	Diamond	127 (0.2)
	Asbestos	318 (0.5)
	*Other	42 591 (63.0)
Length of service (n=67 660)	<10years	34 336 (50.8)
	10-<20years	12 779 (18.9)
	20-30years	15 838 (23.3)
	>30years	4 633 (6.9)
	missing	74 (0.1)

*Other including unknown. Other=”n” + “n [unknown]”

Table 3.2 Certification outcome 2004-2012 financial years

Year*	1st D No T (%)	1st D T (%)	2nd D +T (%)	2nd D No T (%)	2nd D T (%)	Pn** 20-50 (%)	Pn 50-75 (%)	Tcan (%)	T current (%)	T reactive (%)	Total
2004	2545 (27.1)	221 (2.3)	1203(12.8)	167 (1.8)	203 (2.2)	0	0	2390 (25.4)	1873 (19.9)	805 (8.6)	**9407**
2005	2423 (30.5)	237 (3.0)	932 (11.7)	125(1.6)	213 (2.7)	0	0	2932 (36.9)	615 (7.7)	461 (5.8)	**7938**
2006	1310 (28.1)	160 (3.4)	582 (12.5)	68(1.5)	152 (3.3)	0	0	2061 (44.1)	10 (0.2)	327 (7.0)	**4670**
2007	2432(25.3)	352 (3.7)	994 (10.3)	125(1.3)	275 (2.9)	0	1	4174 (43.4)	477 (5.0)	781 (8.1)	**9611**
2008	3731 (27.6)	467 (3.5)	1454 (10.8)	152 (1.1)	324 (2.4)	1	0	4667 (34.6)	1389 (10.3)	1309 (9.7)	**13494**
2009	2208 (27.7)	283 (3.5)	586(7.3)	91(1.1)	170 (2.1)	0	0	898 (11.3)	2903 (36.4)	837 (10.5)	**7976**
2010	1597 (27.2)	264 (4.5)	407(6.9)	55(0.9)	97 (1.7)	0	0	667 (11.3)	2232 (38.0)	558 (9.5)	**5877**
2011	1216(22.9)	214 (4.0)	256(4.8)	39(0.7)	54 (1.0)	0	0	814 (15.3)	2117 (39.9)	593 (11.2)	**5303**
2012	880 (25.3)	152 (4.4)	187(5.4)	34(1.0)	40 (1.1)	0	0	266 (7.6)	1571 (45.1)	351 (10.1)	**3481**
Total	**18342 (27.1)**	**2350 (3.5)**	**6601 (9.7)**	**856 (1.3)**	**1528 (2.3)**	**1 (0.0)**	**1(0.0)**	**18869 (27.8)**	**13187(19.5)**	**6022 (8.9)**	**67757**

*Certification year. Pn**: refers to pneumoconiosis as per the classification used before year 2000, where all the pneumoconioses were reported as Pn irrespective whether it was silicosis, CWP or asbestosis. Pn 20-50: equivalent to first degree and Pn 50-75 equivalent to second degree pneumoconiosis.

Table 3.3 All compensable occupational lung diseases 2004-2012

Certif Year (FY)	ACSOP	Lung cancer	Asbestosis	Meso	AsbestosPD	CWP	OAD	Other	PSS	Silicosis	Silico-TB	TB	Total
2004	**7***(0.1)*	0(0.0)	740 (7.9)	18 (0.2)	964 (10.3)	48(0.5)	259 (2.8)	5 (0.1)	5 (0.1)	920 (9.8)	932 (9.9)	5488 (58.5)	**9386**
2005	**2***(0.0)*	3(0.0)	726 (9.2)	14 (0.2)	882 (11.1)	48 (0.6)	178 (2.2)	2 (0.0)	3 (0.0)	873 (11.0)	753 (9.5)	4438 (56.0)	**7922**
2006	**0***(0.0)*	1 (0.0)	327 (7.0)	9(0.2)	371 (8.0)	26(0.6)	123 (2.6)	0 (0.0)	3 (0.1)	587 (12.6)	514 (11.0)	2702 (57.9)	**4663**
2007	**1***(0.0)*	6 (0.1)	490 (5.1)	18 (0.2)	504 (5.2)	32(0.3)	192 (2.0)	0 (0.0)	7 (0.1)	1 404(14.6)	925(9.6)	6024 (62.7)	**9603**
2008	**1***(0.0)*	6 (0.1)	582 (4.3)	41 (0.3)	753 (5.6)	59(0.4)	253 (1.9)	2 (0.0)	9 (0.1)	2271 (16.8)	1 399(10.4)	8111 (60.1)	**13487**
2009	**0***(0.0)*	4 (0.1)	243 (3.1)	17 (0.2)	361 (4.5)	42(0.5)	200 (2.5)	5 (0.1)	5 (0.1)	1455 (18.3)	558 (7.0)	5075 (63.7)	**7965**
2010	1*(0.0)*	3 (0.1)	131 (2.2)	9 (0.2)	203 (3.5)	46(0.8)	138 (2.4)	0 (0.0)	3 (0.1)	1150 (19.6)	378 (6.4)	3808 (64.9)	**5870**
2011	2*(0.0)*	2 (0.0)	165 (3.1)	8(0.2)	275 (5.2)	19(0.4)	92 (1.7)	1 (0.0)	4 (0.1)	702 (13.3)	232 (4.4)	3786 (71.6)	**5288**
2012	0 *(0.0)*	3 (0.1)	94(2.7)	11 (0.3)	191 (5.5)	20 (0.6)	73 (2.1)	0 (0.0)	1 (0.0)	532 (15.3)	175 (5.0)	2376 (68.4)	**3476**
Total	**14**	**28**	**3498**	**145**	**4504**	**340**	**1508**	**15**	**40**	**9894**	**5866**	**41 808**	**67 660**

FY= Financial year. ACSOP=Allergies due to complex salts of platinum. Meso=Mesothelioma. Asbestos PD= Asbestos Pleural Disease.

PSS=Progressive systemic sclerosis.

3.1.1 Compensable diseases by age, commodity, sex and worker status from 2004-2012

The highest proportion of miners with compensable disease were in the 40-49year age group (34%; n=28 352), followed by the 50-59 year age group (n=23 220; 28.46%), as shown in figures 3.1 a) and 3.1 b).

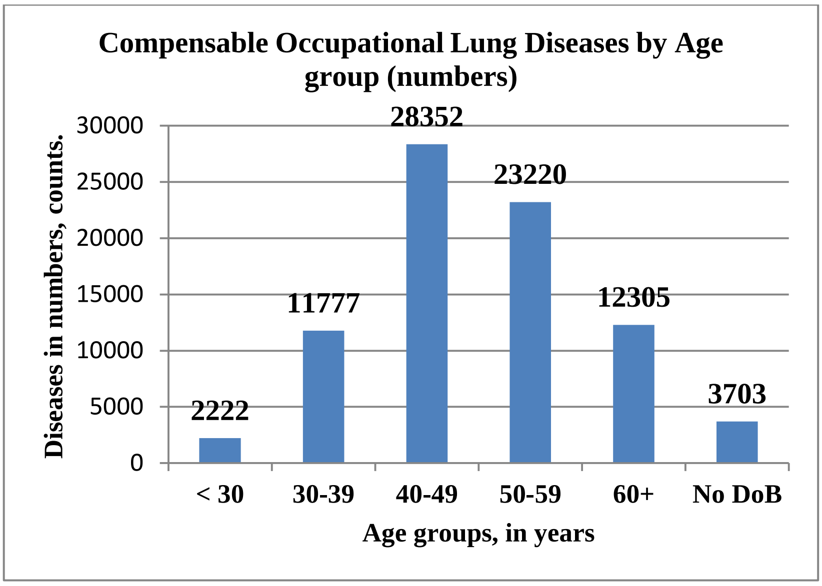


Figure 3.1a) Compensable occupational diseases by age groups in numbers

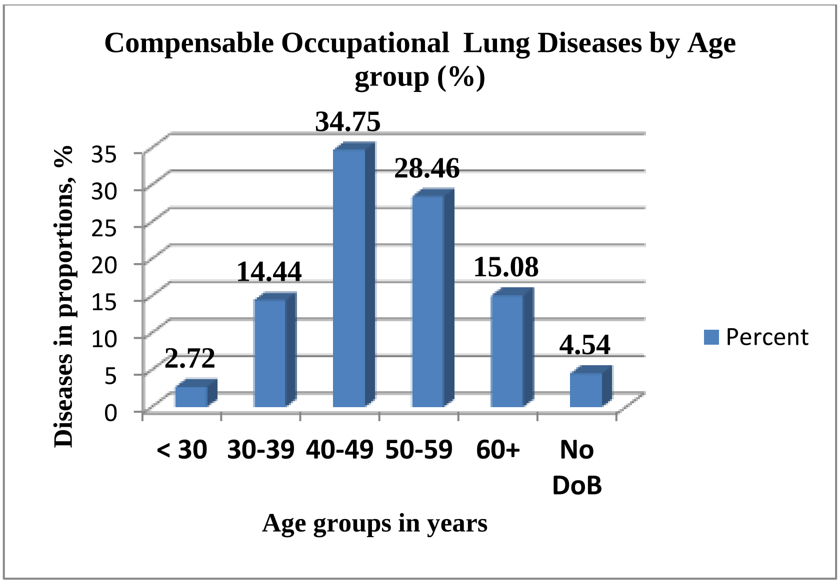


Figure 3.1 b)Proportions of all certified compensable lung diseases by age groups

3.1.2 Compensable occupational lung diseases by commodity, from 2004-2012

Of the 67 660 compensable occupational lung diseases, 5% were from unknown commodity; 30% had maximum mining service in gold mining; almost 5% from platinum group metals and 1% were coal mining. Fifty seven percent had maximum service in mining coded as other commodity (including missing details on commodity).

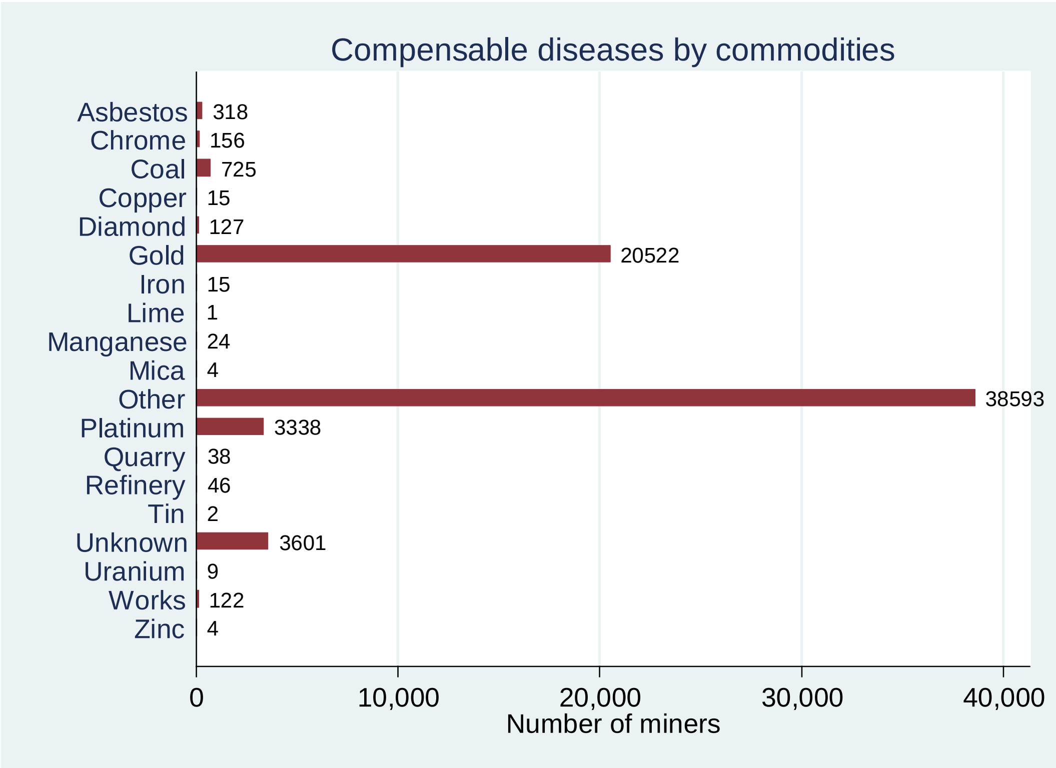


Figure 3.2 Compensable diseases certified between 2004-2012 by maximum service commodity

3.1.3 Compensable lung diseases by population group, sex and worker status

Black miners were by far the majority group with compensable diseases.

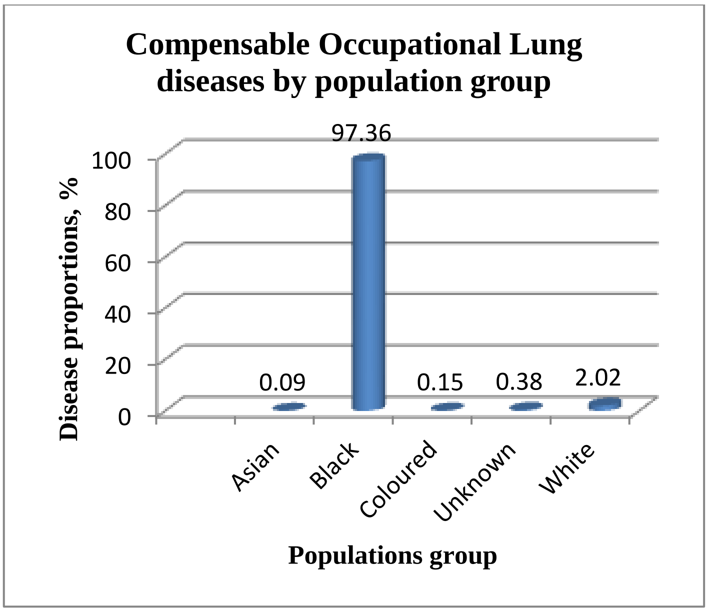


Figure 3.3 Combined compensable occupational diseases by population group

Ninety six percent of the compensable diseases were in men and almost 4% women.

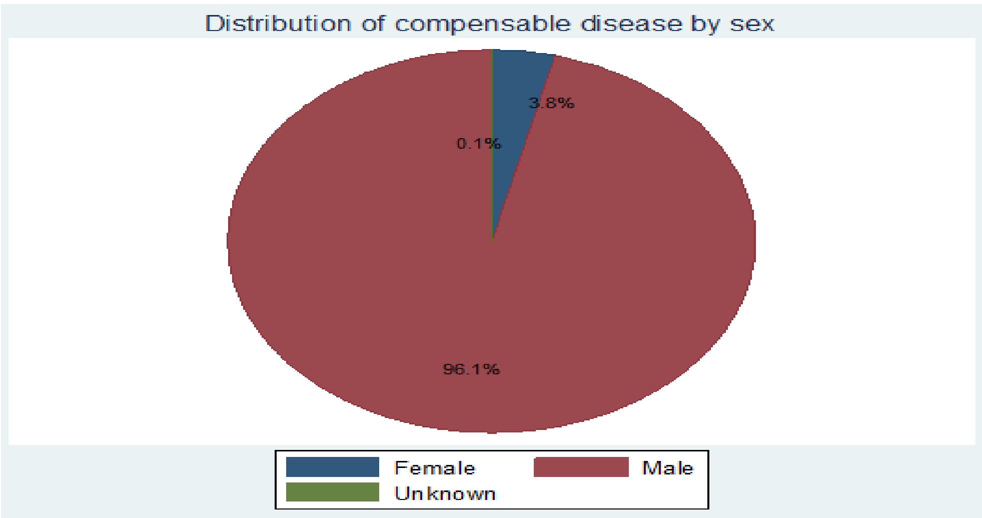


Figure 3.4: Proportions of compensable diseases certified between 2004-2012 by sex

Seventy two percent of the compensable diseases (n=49179) were in active mine workersand almost 25% (n=16 805) in ex-mine workers, as shown in figure 3.5 below.

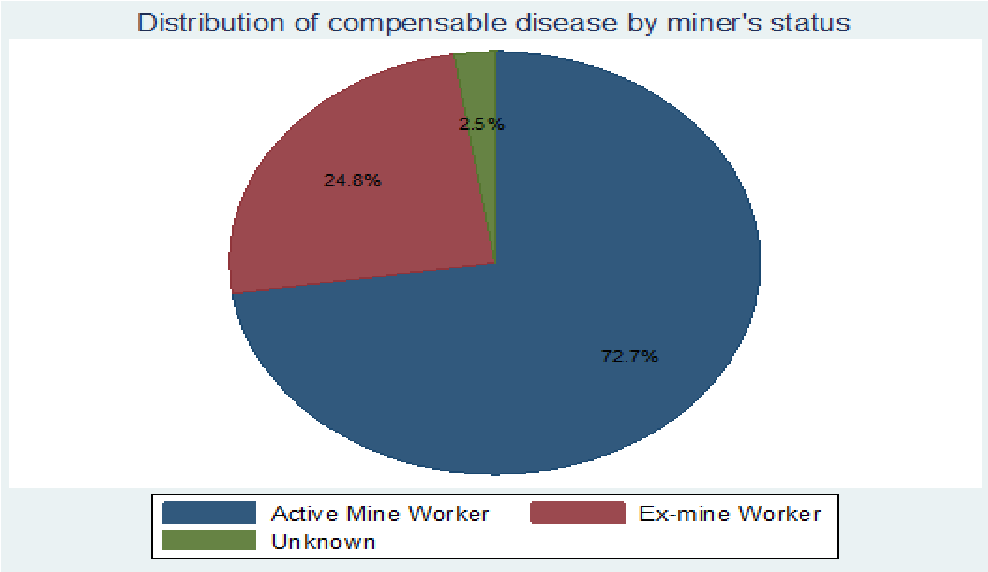


Figure 3.5 Proportions of compensable diseases certified between 2004-2012 by worker status

3.2 Compensable occupational lung disease trends from 2004-2012

3.2.1 Pneumoconiosis trends by commodity

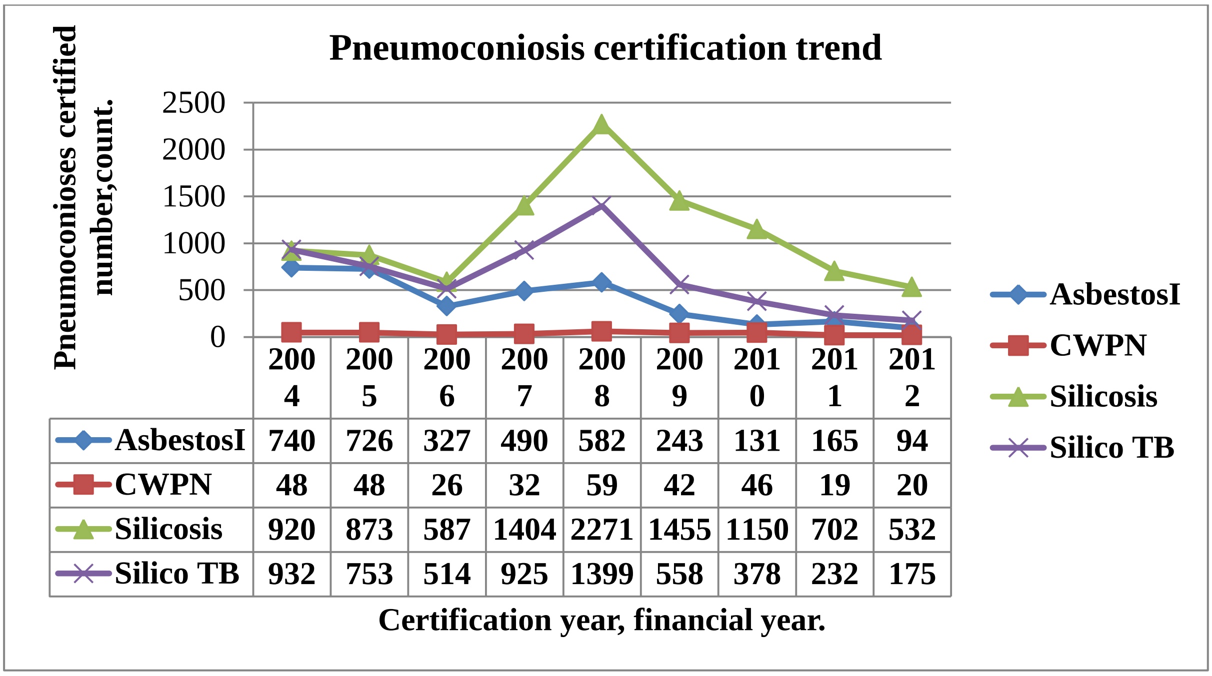
There were 19 531 certified pneumoconioses from 2004 to 2012, in living current (56%) and ex-miners (43 %). The demographic and exposure characteristics of pneumoconiosis certifications are tabled below (Table 3.4).

The mean age of the pneumoconioses cases was 54years and the age group within which most of the pneumoconiosis combined occurred was the 50-59 age group for all, 43% of all the pneumoconioses. A significant proportion of the pneumoconioses had less than four years in the maximum commodity, and the same was found for the individual pneumoconiosis types namely asbestosis (52,2%); coal workers' pneumoconioses (39%); silicosis (41%) and silico-tuberculosis. Nine hundred and sixty seven (5%) of the pneumoconioses were diagnosed in women, and the rest (93%) were in men.

Table 3.4 Description of pneumoconiosis certifications

Variable	Asbestosis	CWPN	Silicosis	Silicosis TB	Total
Age in years: mean (SD)	68 (14)	53.5 (9)	52 (9)	53 (10)	54 (12)
Age group (years):n (%)					
<=39	8 (0.2)	6 (1.9)	157 (1.6)	48 (0.8)	219 (1.1)
40-49	148 (4.3)	84 (25.9)	3229 (32.6)	1865 (31.8)	5326 (27.3)
50-59	668 (19.4)	163 (50.3)	4756 (48.1)	2831 (48.3)	8418 (43.1)
60-69	1129 (32.7)	45 (13.9)	1113(11.3)	622 (10.6)	2909 (14.9)
70+	1358 (39.3)	11 (3.4)	333 (3.4)	129 (2.2)	1831 (9.4)
Missing/Unknown	142 (4.1)	15 (4.6)	306 (3.1)	365 (6.2)	828 (4.2)
Total	3453 (100)	324 (100.0)	9894 (100.0)	5860 (100.0)	19531 (100.0)
Duration of service in years: mean (SD)	7.9 (9.1)	14.7 (13.4)	14.0 (12.6)	16.2 (12.6)	13.6 (12.4)
Duration of service (categories)					
0-4 years	1803 (52.2)	127 (39.2)	4064 (41.1)	1921 (32.8)	7915 (40.5)
5-9years	686 (19.9)	35 (10.8)	975 (9.9)	555 (9.5)	2251 (11.5)
10-14years	397 (11.5)	19 (5.9)	629 (6.4)	348 (5.9)	1393 (7.1)
15-19years	173 (5.0)	24 (7.4)	553 (5.6)	429 (7.3)	1179 (6.0)
20-24years	152 (4.4)	25 (7.7)	1 079 (10.9)	765 (13.1)	2021 (10.3)
25-29	81 (2.4)	34 (10.5)	1264 (12.8)	900 (15.8)	2279 (11.7)
30+	158 (4.6)	60 (18.5)	1 313 (13.3)	927 (15.8)	2458 (12.6)
Missing/Unknown	3 (0.1)	0 (0.0)	17 (0.2)	15 (0.3)	35 (0.2)
Total	3453(100.0)	324 (100.00	9894 (100.0)	5860 (100.0)	19531 (100.0)
Sex					
Women	941 (27.3)	1 (0.3)	19 (0.2)	6 (0.1)	967 (5.0)
Men	2476 (71.7)	314 (96.9)	9784 (98.9)	5728 (97.7)	18302 (93.7)
Missing/Unknown	36 (1.1)	9 (2.8)	91 (0.8)	126 (2.2)	262 (1.3)
Total	3453(100.0)	324 (100.00	9894 (100.0)	5860 (100.0)	19531 (100.0)
Worker status					
Active	297 (8.6)	205 (63.3)	6641 (67.1)	3832 (65.4)	10975 (56.2)
Ex-mine Worker	3101 (89.8)	116 (35.8)	3139 (31.7)	1956 (33.4)	8312 (42.6)
Unknown	55 (1.6)	3 (0.9)	114 (1.2)	72 (1.2)	244 (1.2)
Total	3453(100.0)	324 (100.0)	9894 (100.0)	5860 (100.0)	19531 (100.0)
Certification outcome: n (%)					
First Degree noTB	3101 (89.8)	268 (82.7)	9856 (99.6)	0 (0.0)	13225 (67.7)
Second Degree and TB	229 (6.6)	46 (14.2)	0 (0.0)	5846 (99.8)	6121 (31.3)
Second Degree no TB	123 (3.6)	10 (3.1)	38 (0.4)	14 (0.2)	185 (1.0)
Total	3453 (17.7)	324 (1.7)	9894 (50.7)	5860 (30.0)	19531 (100.0)

Pneumoconiosis certification trends are shown in Figure 3.6 below. Certification for silicosis and silico-TB were similar in 2004, and above asbestosis certification. All three showed a decline in 2006 and significantly peaked in 2008. After 2008, all three showed downward trends up to 2012. Certification for Coal Workers' pneumoconiosis and other pneumoconiosis remained low over the years, and throughout the period under review. The trends for certification of Interstitial asbestosis (p=0.01) and Silico-TB (p=0.038) were statistically significant, both falling over time. Certification trends for silicosis (p=0.63), Coal workers' pneumoconiosis (p=0.10), and other pneumoconiosis (p=0.111) were not statistically significant.



	2004	2005	2006	2007	2008	2009	2010	2011	2012
AsbestosI	740	726	327	490	582	243	131	165	94
CWPN	48	48	26	32	59	42	46	19	20
Silicosis	920	873	587	1404	2271	1455	1150	702	532
Silico TB	932	753	514	925	1399	558	378	232	175

Figure3.6 Pneumoconiosis certification trends, 2004-2012

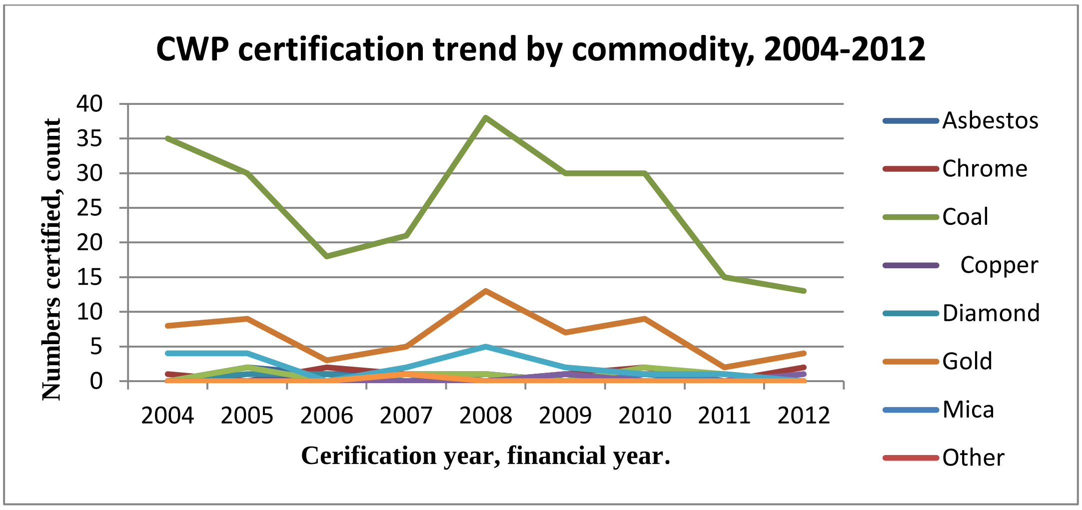


Figure 3.7 Certification trend for CWP by commodity, 2004-2012

Silicosis certification trends

Silicosis certification trends from 2004 to 2012 show that silicosis was predominantly in the gold mining sector, with only a small contribution from other commodities as shown below, in Figure 4.8. The trend was not statistically significant **(nptrendz = -0.47; p value >0.05).** A similar trend was observed for silicosis and tuberculosis in the gold the gold mining sector, significantly above all other commodities, as shown in Figure 3.9.

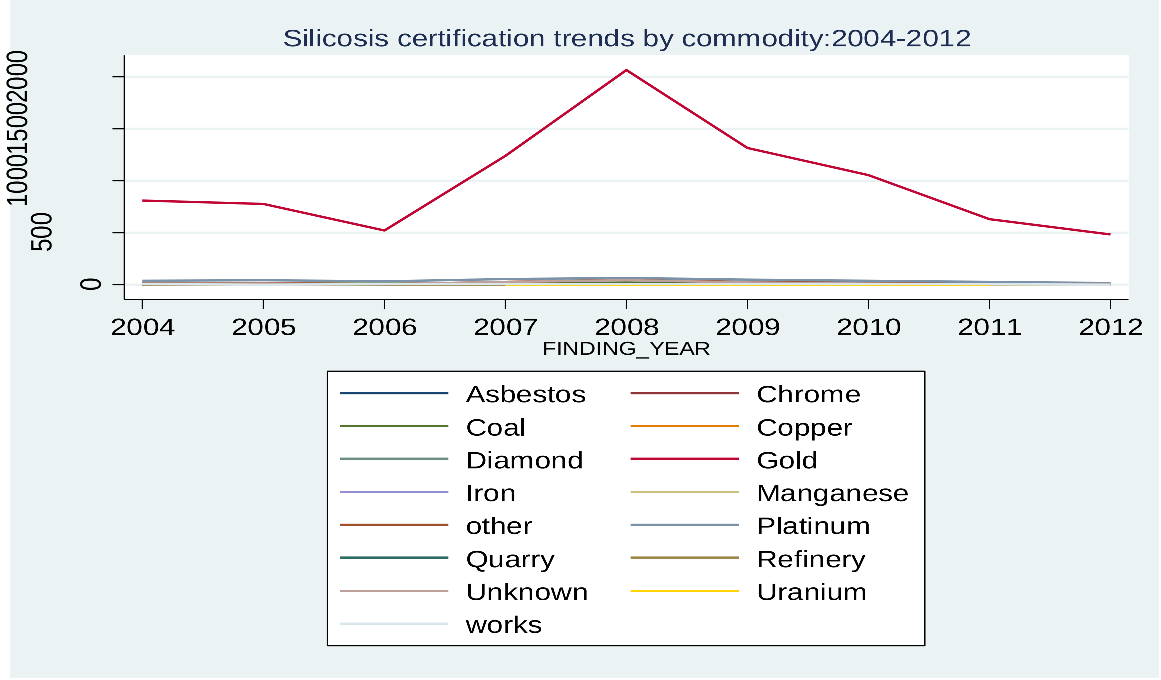


Figure 3.8 Silicosis certification trends by commodity(FINDING_YEAR= certification year.)

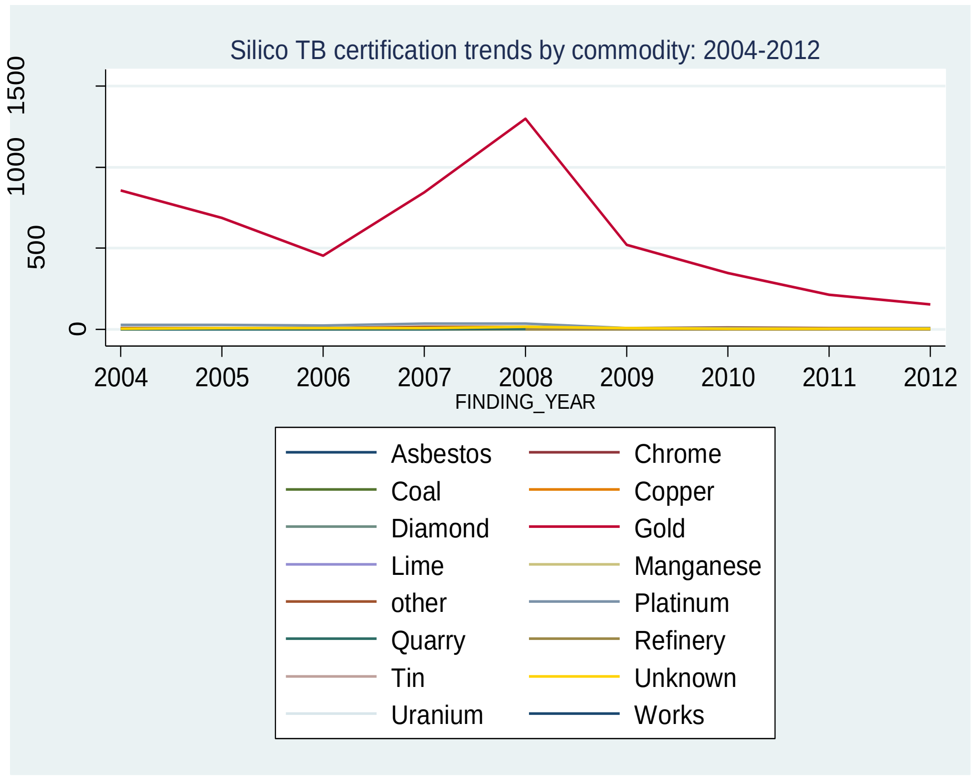


Figure 3.9 Silico-TB certification trends by commodity(FINDING_YEAR= certification year.)

3.2.2 TB certification trends 2004-2012

The tuberculosis certifications constituted current miners as majority (88.6%; n=37039) throughout the period under study, and ex-miners being minority (8.3%, n=3461) as shown in Figure 3.10. The TB certification trends suggest that a downward trend from 2004 to 2006, a sharp upward trend in 2007 and 2008, thereafter a sharp decline in 2009 and a steady decline from 2009 to 2012.

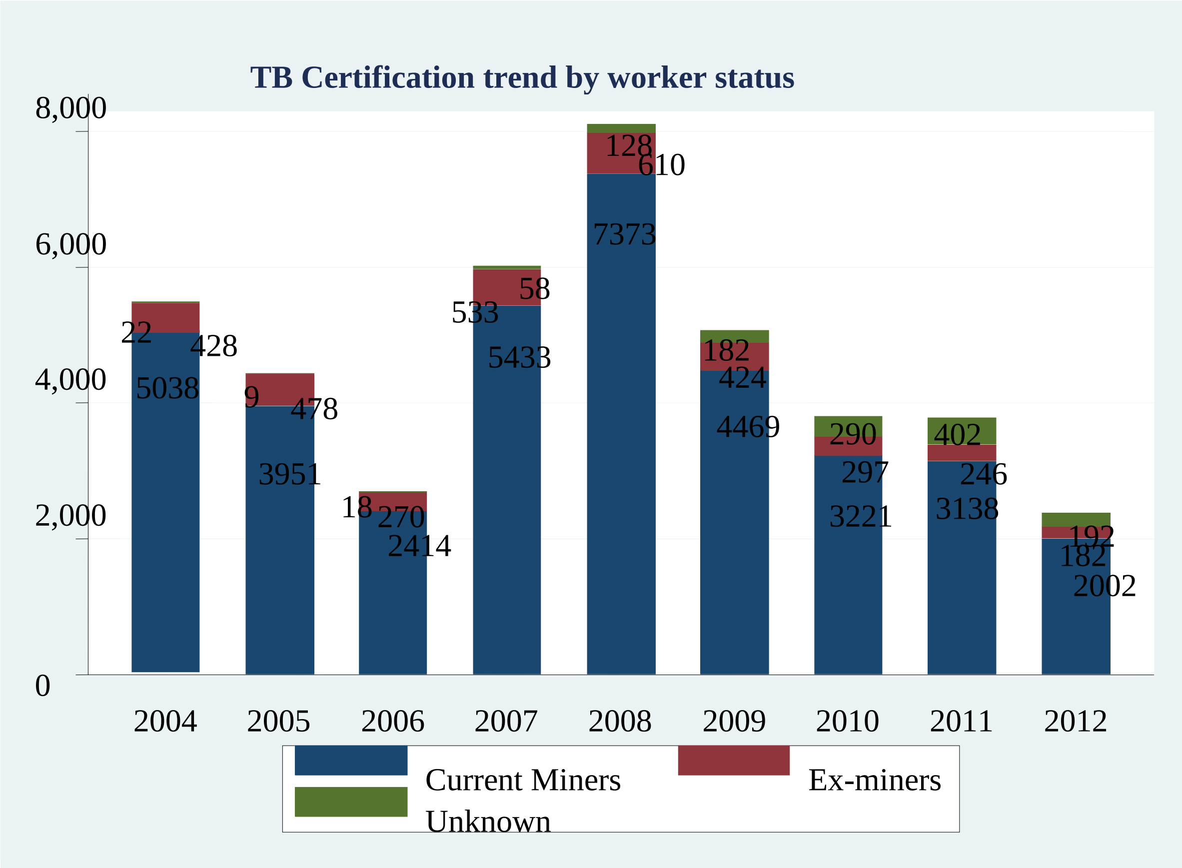


Figure 3.10 TB Certification trends by worker status, 2004-2012

Table 3.3 below summarizes descriptive characteristics and distribution of TB certifications by different TB certification categories namely 1ST degree, 2nd degree TB, TBcan antedate, Tb current and reactivated TB. The median age in years in all categories was between 44years, and the age group category with maximal contribution to the certifications was 40-50years.

Table 3.3 Descriptive characteristics of tuberculosis certification 2004-2012 (FY)

Variable	1st D T	2nd DT	T can Antedate	T current	T reactive	Total
Age in years (median ,IQR)	48 (10)	49 (10)	43 (10)	44 (12)	45 (9)	44 (11)
Age group (years, %)						
<30	11 (0.5)	5 (0.4)	867 (4.6)	822 (6.2)	58 (1.0)	1763 (4.2)
30-39	250 (10.7)	110 (7.9)	4729 (25.1)	3400 (25.8)	1089 (1.0)	9578 (22.9)
40-49	1043 (44.6)	578 (41.6)	8157 (43.2)	5755 (43.6)	3161 (52.5)	18694 (44.7)
50-59	803 (34.3)	509 (36.6)	3192 (16.9)	2767 (21.0)	1412 (23.5)	8683 (20.8)
60-69	120 (5.1)	92 (6.6)	218 (1.2)	166 (1.3)	66 (1.1)	662 (1.6)
70+	13 (0.6)	11 (0.8)	20 (0.1)	15 (0.1)	6 (0.1)	6 (0.2)
Missing	100 (4.3)	85 (6.1)	1686 (8.9)	262 (2.0)	230 (3.8)	2363 (5.7)
Total	2340 (100)	1390 (100)	18869 (100)	13187 (100)	6022 (100)	41808 (100)
Commodity						
Asbestos	33 (1.4)	30 (2.2)	106 (0.6)	35 (0.3)	24 (0.4)	228 (0.6)
Coal	48 (2.1)	31 (2.2)	515 (2.7)	248 (1.9)	50 (0.8)	892 (2.1)
Gold	1978 (84.5)	1199 (86.3)	15260 (80.9)	9753 (74.0)	5316 (88.3)	33506 (80.1)
Platinum	161 (6.9)	73 (5.3)	1960 (10.4)	2211 (16.8)	446 (7.4)	4851 (11.6)
Quarry	4 (0.2)	6 (0.4)	73 (0.4)	22 (0.2)	7 (0.1)	112 (0.3)
Refinery	6 (0.3)	4 (0.3)	74 (0.4)	43 (0.3)	12 (0.2)	139 (0.3)
Works	9 (0.4)	5 (0.4)	68 (0.4)	34 (0.3)	19 (0.3)	135 (0.3)
Other	98 (4.2)	40 (2.9)	800 (4.2)	826 (6.3)	147 (2.4)	1911 (4.6)
Missing	3 (0.1)	2 (0.1)	13 (0.1)	15 (0.1)	1 (0.0	34 (0.1)
Total	2340 (100)	1390 (100)	18869 (100)	13187 (100)	6022 (100)	41808 (100)
Miner status						
Active miner	1665(71.2)	900 (64.8)	17073 (90.5)	11 993(91.0)	5408 (89.8)	37039 (88.6)
Ex-miner	626 (26.8)	472 (34.0)	1383 (7.3)	540 (4.0)	440 (7.3)	3461 (8.3)
Missing	49 (2.1)	18 (1.3)	413 (2.2)	654 (5.0)	174 (2.9)	1308 (3.1)
Total	2340 (100)	1390 (100)	18869 (100)	13187 (100)	6022 (100)	41808 (100)
Sex						
Female	7 (0.3)	8 (0.6)	124 (0.7)	188 (1.4)	19 (0.3)	346 (0.8)
Male	2306 (98.6)	1354 (97.4)	17994 (95.3)	12916 (97.9)	5924 (98.3)	40494 (96.9)
Missing	27 (1.1)	28 (2.0)	751 (4.0)	83 (0.6)	79 (1.3)	968 (2.3)
Total	2340 (100)	1390 (100)	18869 (100)	13187 (100)	6022 (100)	41808 (100)

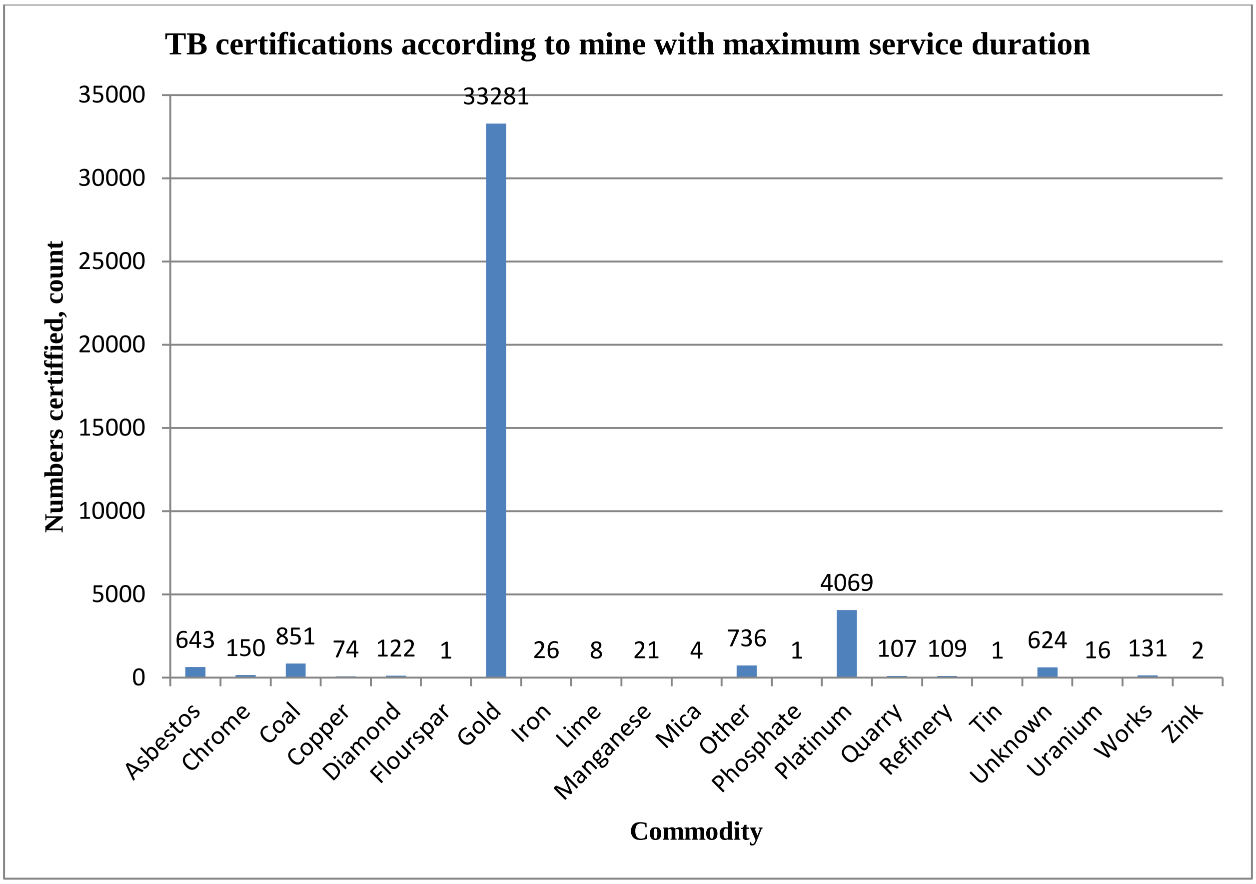


Figure 3.11 Compensable Tuberculosis by commodity

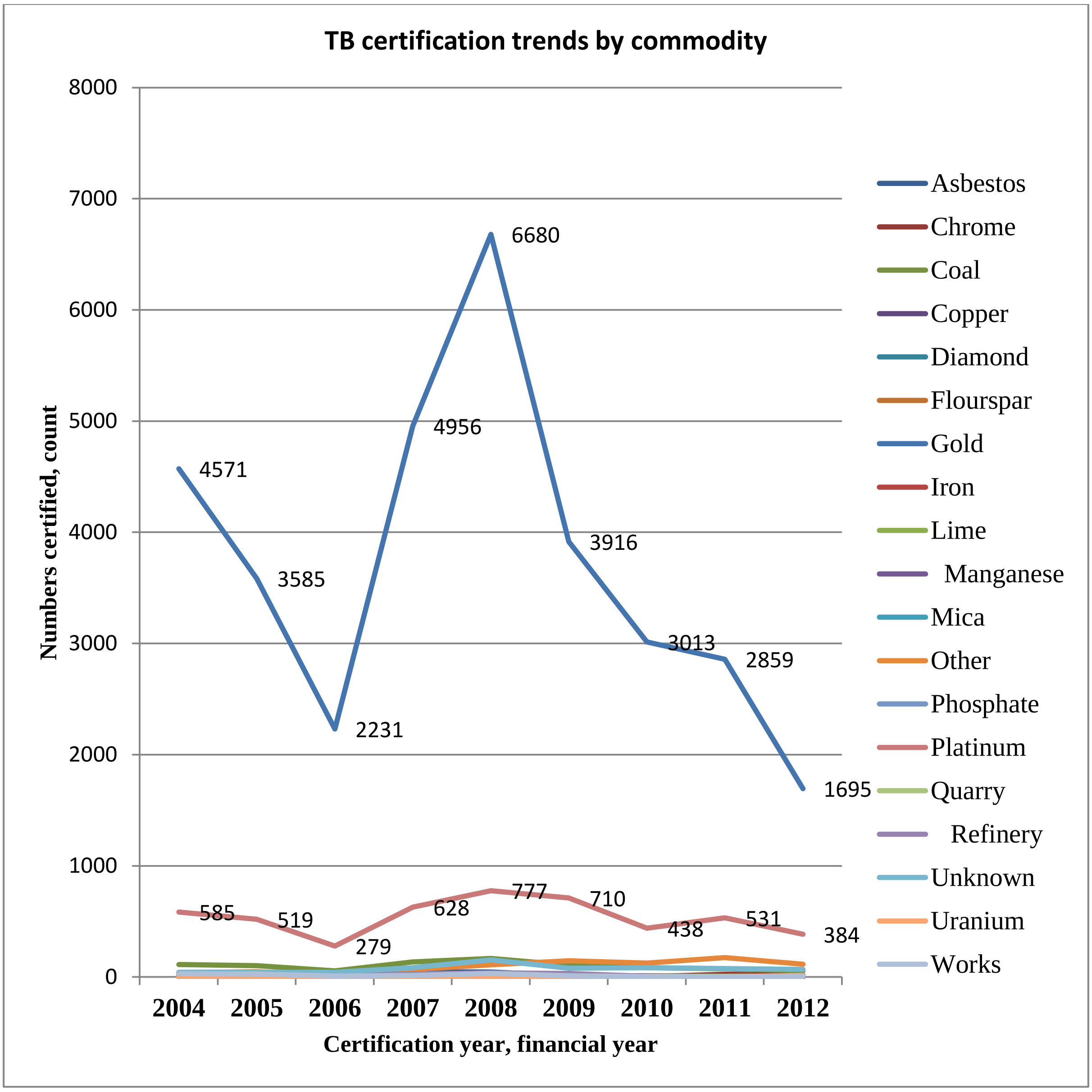


Figure 3.12Compensable tuberculosis certification trend by commodity

The certification trends for the diseases all showed a common trend of an upward pattern in 2007, peaking in 2008. These are likely to be an artifact of the through-put of the certification committee, and not likely to be true disease trends. However there was no documented information to verify the number of committee meetings and numbers seen in the 2007 and 2008 years compared to other years.

3.3 Specific issues related to some of the certified lung diseases

3.3.1 Silicosis in platinum miners

Of the 6662 certifications of living miners and ex-miners with maximum service in the platinum mines, 544 were certified with silicosis, during the period under study. The characteristics of cases with silicosis are summarized in table 3.5 below. Of these, onewas a woman, certified in 2008, 539 (99%) were men and the sex of three cases wasunknown.Three hundred and sixty two certifications (66.5%) were of the first degree with no tuberculosis, 181 (33%) were silicosis and tuberculosis awarded a second degree impairment, and one case was awarded with second degree silicosis with no tuberculosis. Seventy three percent (n=396) of the certified cases were current miners and 26% (n=140) were ex-miners.

The median age of the certified cases was 51years (range 33- 95years). Majority of the certified cases were in the 50-59 age group, followed by 35% in the 40-49year age group. The lowest number of cases was in the youngest group namely the 30-39 years, and none of the certified cases were younger than 30 years at the time of claim submission.

The mean duration of service for this group was approximately six years (with 9.3 years standard deviation); majority of certified cases had less than ten years of service in the platinum mines, 69% in the 0-4 years group and 11% in the 5-9 years group. Of note, the one male ex-miner, certified in 2008, had less than one year’s service in the platinum mine, yet he was classified in this category of claimants with maximal service in platinum mining.

Table 3.5 Characteristics of Platinum miners certified with silicosis, 2004-2012

Variable	1st D no T	2nd D +T	2nd DnoT	Total
Age, years (continuous): Mean (SD)	52.5 (7.2)	52.3 (7.4)	65	52 (7)
Age group: n (%)				
<30	0	0	0	
30-39	3 (0.8)	2 (1.1)	0 (0.0)	5 (1)
40-49	125 (34.5)	63 (34.8)	0 (0.0)	188 (34.6)
50-59	168 (46.4)	89 (49.2)	0 (0.0)	257 (47)
60-69	42 (11.6)	12 (6.6)	1 (100.0)	55 (10)
70+	7 (1.9)	5 (2.8)	0 (0.0)	12 (2,2)
Unknown	17 (4.7)	10 (5.5)	0 (0.0)	27 (5)
Total	362 (100%)	181 (100%)	1(100%)	544 (100%)
Duration of service-years(continuous): Mean (SD)	6.1(9.6)	5.6 (8.6)	0	5.9 (9.3)
Total	362	181	1	544
Duration of service-group in years: n(%)				
0-4 years	253 (69.9)	123 (68)	1 (100.0)	376 (69)
5-9years	39 (10.8)	23 (12.8)	0 (0.0)	62 (11.4)
10-14years	19 (5.3)	15(8.3)	0 (0.0)	34 (6.3)
15-19years	8 (2.2)	5 (2.8)	0 (0.0)	13 (2.4)
20-24years	8 (2.2)	1 (0.6)	0 (0.0)	9 (1.7)
25-29	20 (5.5)	5 (2.8)	0 (0.0)	25 (4.6)
30+	15 (4.1)	9 (5.0)	0 (0.0)	24 (4.4)
Total	362 (100%)	181 (100%)	1(100%)	544 (100%)
Sex: n (%)				
Women	0	1 (0.6)	0	1(0.2)
Men	361(99.7)	178 (98)	1	539 (99)
Missing/Unknown	1 (0.3)	2 (1.1)	0	3(0.6)
Total	362 (100%)	181 (100%)	1(100%)	544 (100%)
Worker status: n(%)				
Active	264 (73%)	132 (73%)	0	396 (72.8)
Ex-mine Worker	94 (26%)	46 (25.4%)	1	141(25.9)
Unknown	4 (1%)	3 (1.7%)	0	7 (1.3)
Total	362 (100%)	181 (100%)	1(100%)	544 (100%)
Total	362 (66.5%)	181 (33%)	1 (0.2%)	544 (100%)

Certification trend for silicosisin platinum miners from 2004 to2012

The number of silicosis certifications in platinum miners was 63 in 2004, had an upward increase and peaked to 101 in 2008 but declined over the next four year period to 22 in the 2012 financial year, as shown in Figure 3.11, table 3.4 and Figure 3.12. However, there was no statistically significant downward trend in compensable silicosis in platinum miners between 2004 and 2012 ($z=-1.89$; $p>0.05$). The extent of compensable silicosis certified in platinum miners was mostly of the 1^{st} degree with no tuberculosis and silicosis with tuberculosis (2nd Degree + TB), one case was certified as 2^{nd} degree with no TB.

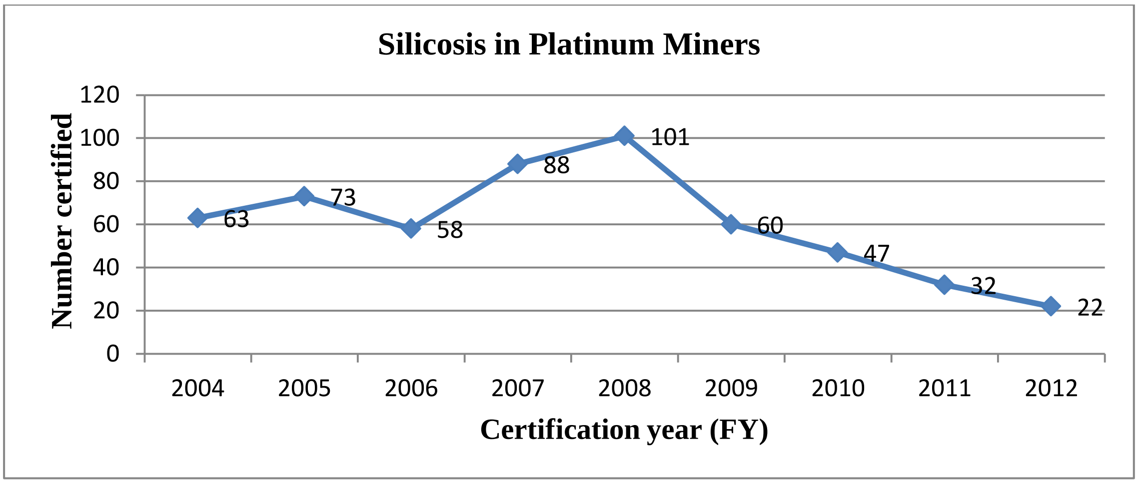
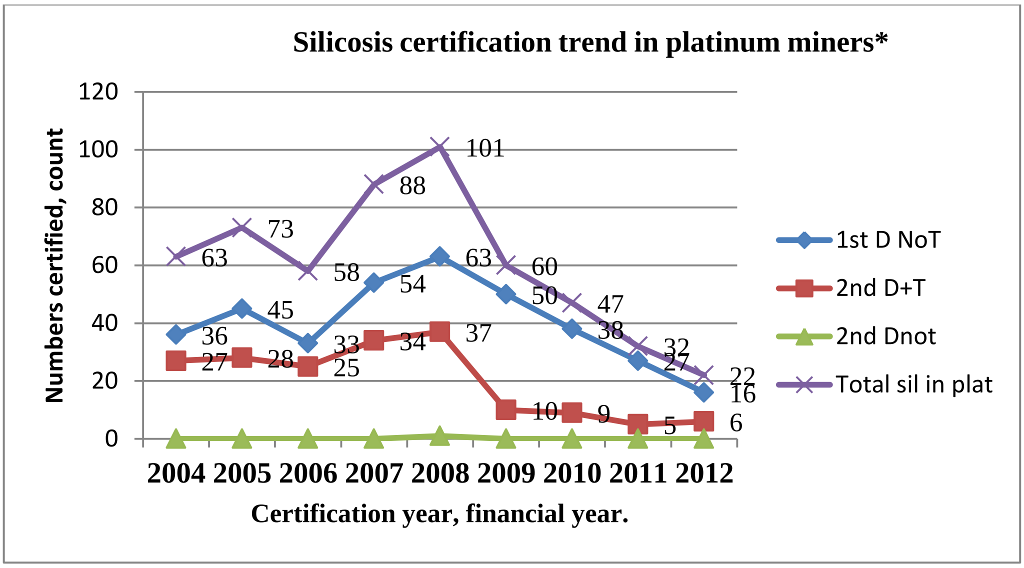


Figure 3.13Certification trend for silicosis in platinum miners

The extent of silicosis certified each year is further broken down as shown Table 3.6 and Figure 3.14 below.

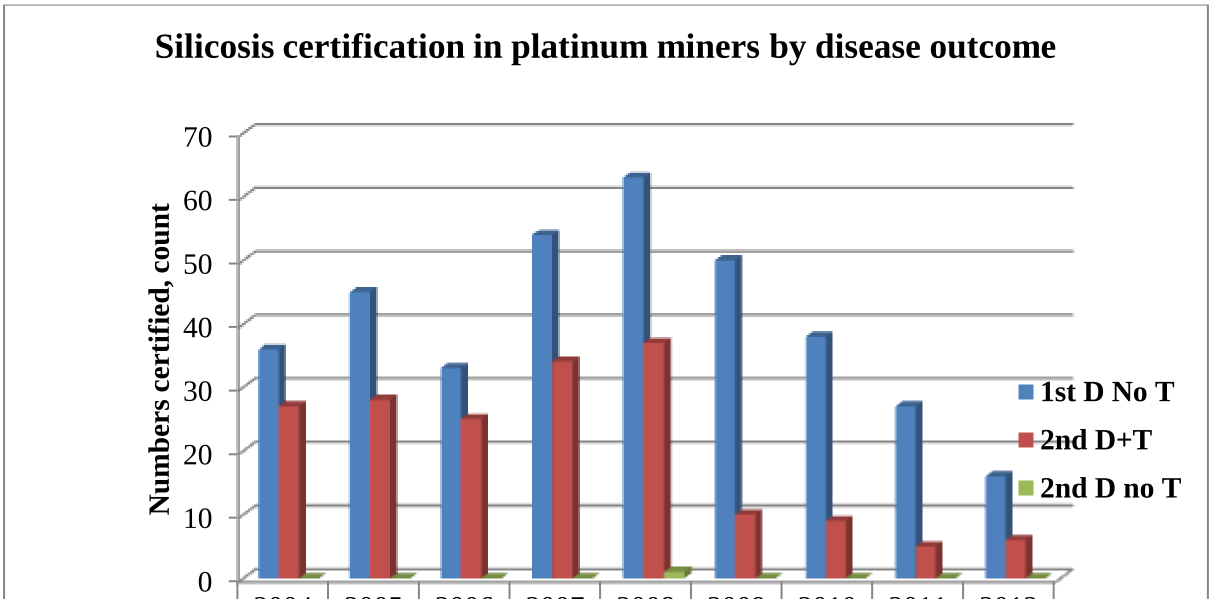
Table 3.6 Compensable silicosis certified in platinum miners by year, 2004-2012

Certification Year	1st D NoT	2nd D+T	2nd D no T	Total Silicosis
2004	36	27	0	63
2005	45	28	0	73
2006	33	25	0	58
2007	54	34	0	88
2008	63	37	1	101
2009	50	10	0	60
2010	38	9	0	47
2011	27	5	0	32
2012	16	6	0	22
Total	362	181	1	544



*Current and ex-miners with maximum service in platinum mining.

Figure 3.14 (a) Certification trend for silicosis in platinum miners, by extent of disease



	2004	2005	2006	2007	2008	2009	2010	2011	2012
1st D No T	36	45	33	54	63	50	38	27	16
2nd D+T	27	28	25	34	37	10	9	5	6
2nd D no T	0	0	0	0	1	0	0	0	0

Figure 3.14(b) Certification trend for silicosis in platinum miners, by extent of disease

Silicosis in current and ex-miners with exclusive platinum mining

Verification of service records for platinum miners with silicosis revealed that none had exclusive platinum mining. Therefore there was no silicosis certification from exclusive platinum mining.

3.3.2 Duration of service in miners with coal workers' pneumoconiosis by coal type mined, anthracite vs. bituminous

There were 340 certifications of compensable coal workers pneumoconiosis, however 21.5% of these (n=73) had missing mine details and were not included in the analysis. Two hundred and sixty sevencoal workers' pneumoconiosis cases were used for the analysis of which 3.4% (n=9) were from anthracite coal type mines, 91% (n=243) from bituminous coal mines and 5.5% (n=15) from unknown coal mines, as shown in Table 3.7 below. The mean duration of service in all coal workers' pneumoconiosis certification was 18.5 years (standard deviation 12.5years). The mean duration of service by coal type mined was 14.8 years (SD 10.8) for the anthracite coal type (n=9), 20.7 years (SD11.4) for bituminous coal type (n=243), 18.3 years for unknown coal type (n=15). There was no statistically significant difference between the means of service duration for the two groups (p>0.05), as well as with regards to duration of service categories in years (Fischer's exact =0.061).

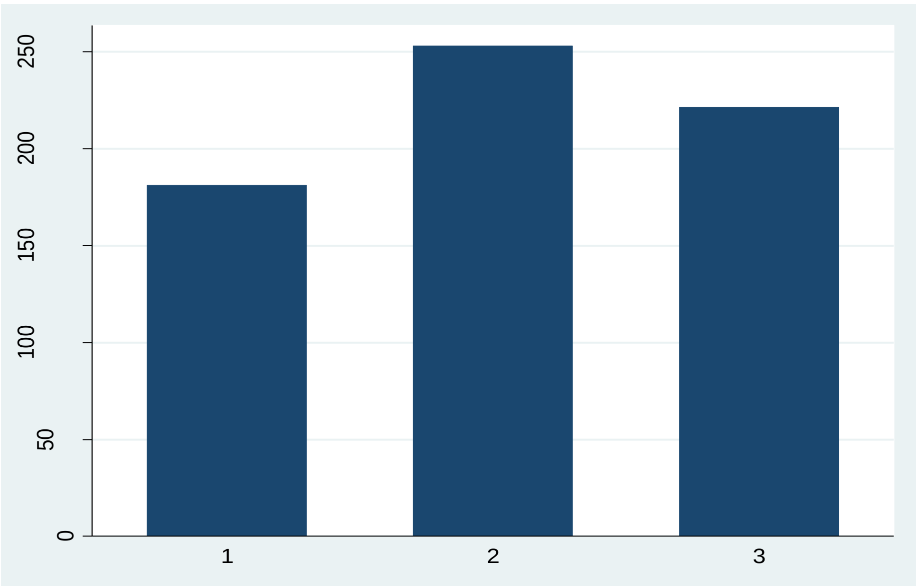


Figure 3.15 Service duration (in months) among cases certified with coal workers' pneumoconiosis (1=anthracite, 2=bituminous and 3=unknown coal mine)

Table 3.7 Coal workers' pneumoconiosis by coal type and service duration

Service duration groups (years)	Anthracite	Bituminous	Unknown Coal mine	Total
0-4	**2**	**33**	**3**	**38**
5_9	**2**	**15**	**3**	**20**
10_14	**0**	**22**	**1**	**23**
15_19	**1**	**30**	**0**	**31**
20_24	**2**	**39**	**0**	**41**
25_29	**1**	**43**	**6**	**50**
30+	**1**	**61**	**2**	**64**
Total	9 (3.4%)	243 (91%)	15 (5.5%)	267

Pearson chi2 (12)=18.0402 (p<0.05) Fischer's exact= 0.061

3.3.3 Asbestos related diseases in women

Two thousand, two hundred and forty one compensable asbestos related diseases were certified in women. Fifty five percent of these (n=1241) were asbestos pleural disease in the 1^{st} degree, thirty percent (n= 670) were asbestos pleural and interstitial diseases in the 1^{st} degree, eleven percent (n=249) were interstitial asbestosis in the first degree and all other diseases constituted less than 10% of the asbestos related diseases in women. Thirty one diseases were certified as first degree with concurrent pulmonary TB also diagnosed. There were twenty eight non malignant, asbestos related diseases in the second degree, one was interstitial asbestosis, nine were asbestos pleural diseases and eighteen were asbestos pleural and interstitial diseases. Asbestos malignant diseases were found in ten women, one woman with asbestos lung cancer and nine with mesothelioma, both second degrees. Figure 3.16 illustrates the respective disease proportions of asbestos related diseases in women certified from 2004 to 2012 financial years.

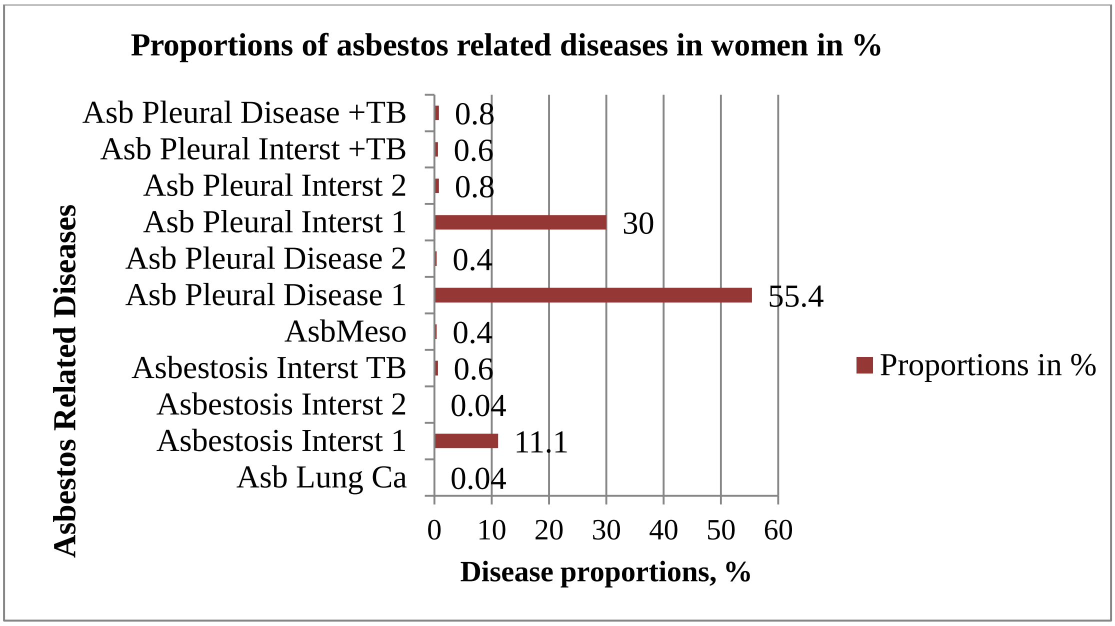


Figure 3.16 Proportions of asbestos related diseases certified in women, 2004-2012 financial years

None of the women certified with asbestos related diseases were younger than 30 years of age. Almost fifty percent (n=1106) of asbestos related diseases occurred in women above seventy years age group, followed by 28% (n=629) and 15% (n=345) in the 60-69 and 50-59 age groups respectively. The least number of asbestos related diseases were in the 30-39 age group (n=5). The average duration of service for all women certified with asbestos related diseases was approximately seven years (mean=6.97years, SD 6.37years).

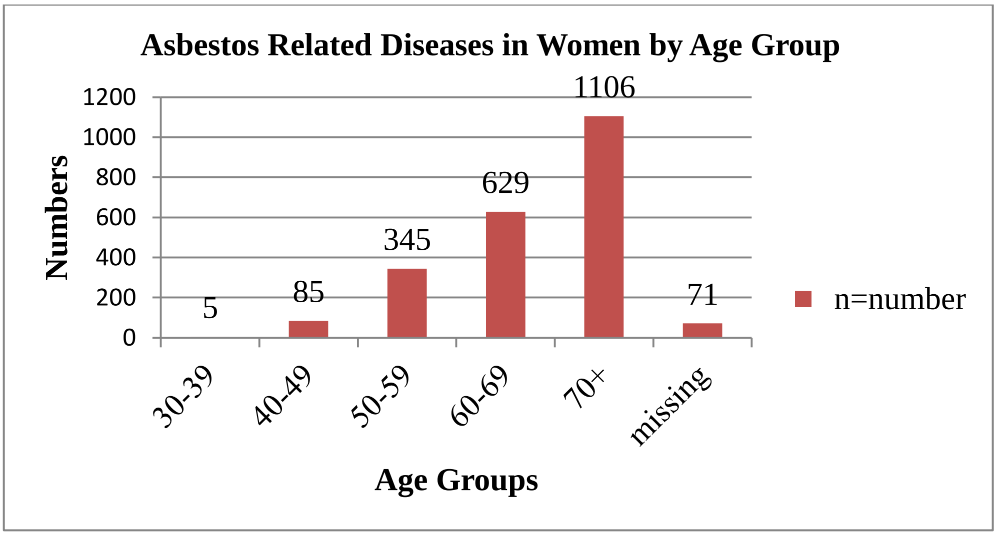


Figure 3.17Asbestos related diseases in women by age group, certified 2004-2012

3.3.4 Mesothelioma certification in diamond miners, 2003-2012

Of the 145 mesothelioma cases, three had maximum service in the diamond mines; however verification from service records revealed that there were only two mesothelioma certifications with maximum service in diamond mines. The two cases had exclusive diamond mining exposure, as shown below. Table 3.8 below describes characteristics of mesothelioma cases with exclusive diamond mining exposure.

Table 3.8 Descriptive characteristics of the mesothelioma cases with exclusive diamond mining

Characteristics	Case 1	Case 2	Case 3
Sex	Male	Male	Male
Population group	Black	Coloured	Black
Worker status	Ex-miner	Ex-miner	Ex-miner
Finding type description	2^{nd} D noT	2^{nd} D noT	2^{nd} D noT
Max service mine, mine type (start date- end date)	Four months: Gold (14/02/1972-28/02/1973) Four months: Diamond (09/01/1984-04/05/1984) Four months: Asbestos (05/05/1971-03/01/1972)	302months (01/01/1968-01/03/1993)	14months (03/11/1978-21/01/1980)
Service Records Verification	4 months: Diamond (09/01/1984-04/05/1984) 12months: Gold (14/02/1972-28/02/1973) 8 months: Asbestos (05/05/1971-03/01/1972)	Diamond	Diamond
Age at claim (years)	60	68	43
Finding date*	12/06/2012	13/08/2008	07/04/2008

*Certification date.

3.4 Time to compensation from certification

Three hundred and eighty nine certified cases were selected in the final sample to be used for calculation of time to compensation. Of the 389 cases, 172 (44%) were certified in 2009, 129 (33%) certified in 2010 and 88 (23%) certified in 2011. Three hundred and thirty one of the diseases (85%) were first degree silicosis, three were asbestos pleural and interstitial disease of the second degree, 29 first degree asbestos pleural and interstitial disease; 22 first degree asbestos interstitial disease (asbestosis) and four were mesothelioma (second degree). Table 3.9 below summarizes the cases according to certification years and diagnosis with severity (disease degree).

Table 3.9A sample of compensable occupational lung diseases following certification in 2009, 2010 and 2011

Disease Degree	2009	2010	2011	Total
Asbestosis Interstitial 1st D	8	7	7	22
Asbestos Mesothelioma 2nd D	2	1	1	4
Asbestosis Pleural and Interstitial 1st D	14	6	9	29
Asbestosis Pleural and Interstitial 2nd D	2	0	1	3
Silicosis 1st D	146	115	70	331
Total	**172**	**129**	**88**	**389**

Of the 389 sample selected for follow up, 26.5% (n=103) had been compensated as at the end of 2014 financial year (2014 March25). Sixty three cases of these 103 (61%) had been certified in 2009, twenty three (22%) in 2010 and seventeen certified (17%) in 2011, as illustrated in Figure 3.18 below.

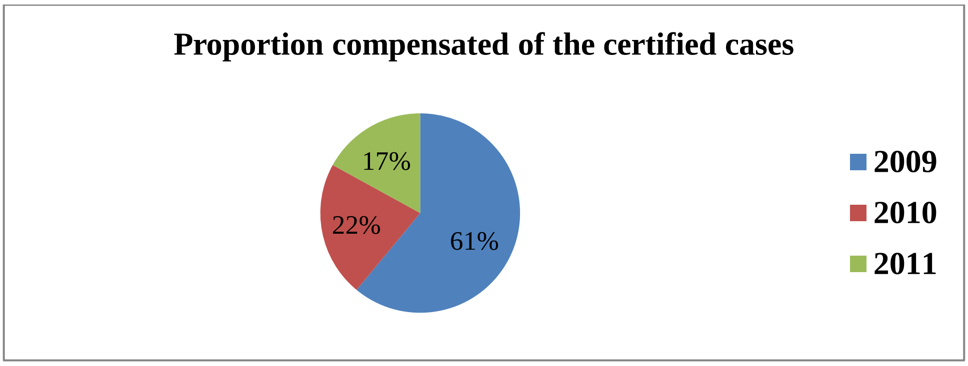


Figure 3.18 Proportion of the certified cases that were compensated by the end of 2014 financial year

The cases compensated comprised 37% of the certified sample from 2009, 18% of the 2010 cases and 19% of the 2011, illustrating a downward trend towards the cut-off point of the end of 2014 financial year (figure 3.19).

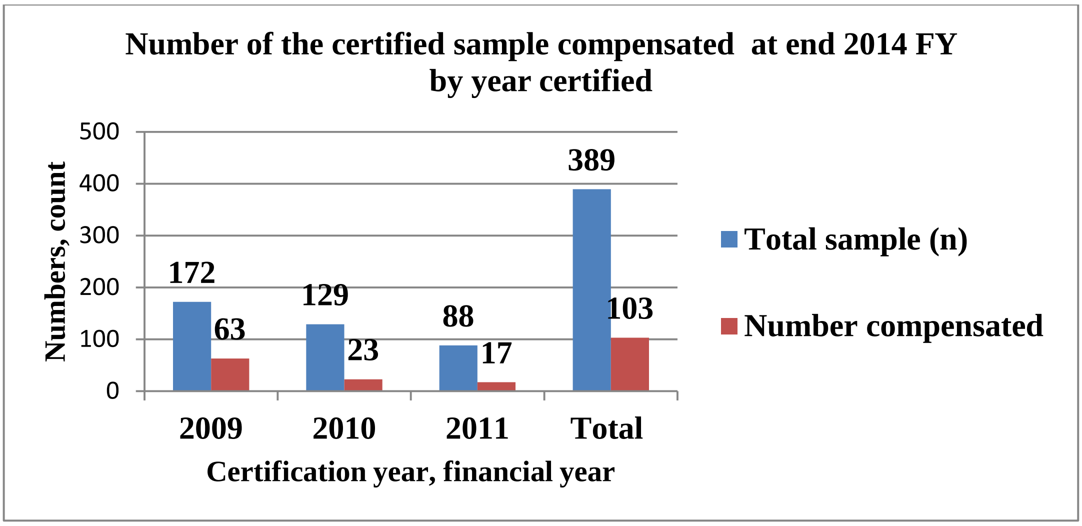


Figure 3.19 Certified cases selected per year, and number compensated by end of 2014 financial year

The compensated cases are further tabled below according to diseases compensated by certification year (Table 3.10), diseases compensated by year of compensation (Table 3.11), and certification year by compensation year (Table 3.12)

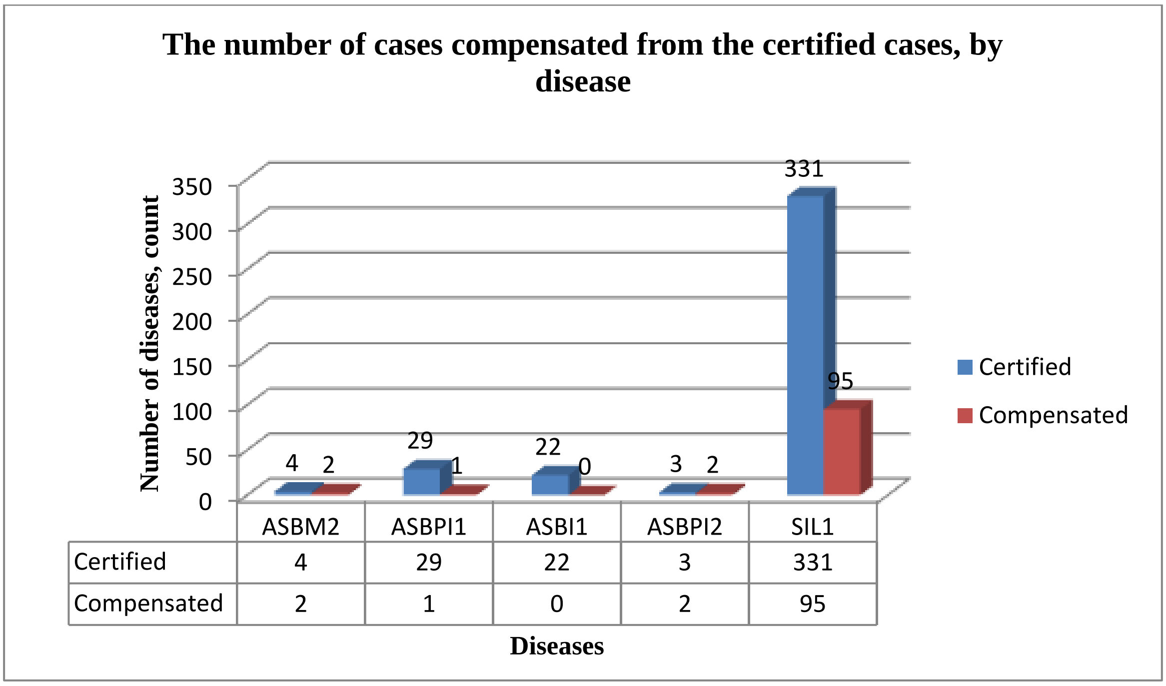
Table 3.10 Numbers of compensated diseases from the sample, by certification year

Disease Degree	2009	2010	2011	Total
Asbestosis Interstitial 1st D	0	0	0	0
Asbestos Mesothelioma 2nd D	2	0	0	2
Asbestosis Pleural and Interstitial 1st D	1	0	0	1
Asbestosis Pleural and Interstitial 2nd D	2	0	0	2
Silicosis 1st D	58	23	17	98
Total n (% of the original sample)	**63 (36.6%)**	**23 (17.8%)**	**17 (19.3%)**	**103(26.5%)**

The number of compensated cases by disease and the percentage of compensated cases from the certified are shown in Table 3.11and figure 3.20below.

Table 3.11 Proportion of diseases compensated from certified (FY)

Compensated	ASBM2	ASBPI1	ASBI1	ASBPI2	SIL1	Total
Number of cases compensated	2	1	0	2	98	103
Diseases compensated as % of certified	50%	3.40%	0	66.70%	28.7	(26.5%)



	ASBM2	ASBPI1	ASBI1	ASBPI2	SIL1
Certified	4	29	22	3	331
Compensated	2	1	0	2	95

Figure 3.20 Number of compensated cases by disease from the certified cases

Table 3.12 Number of diseases compensated from financial year, by compensation year

Certification year	Year Compensated 2010	2011	2012	2013	2014	Total
2009	5	5	24	26	3	63
2010	1	0	0	19	3	23
2011	0	1	3	10	3	17
Total	**6**	**6**	**27**	**55**	**9**	**103**

Time to compensation

Table 3.13 below shows the time to compensation by year of certification. The mean time to compensation for the cases certified in 2009 was approximately 38 months, minimum four months and 53 months maximum (SD 11.5 months); 35.8 months (minimum 1.6 months and maximum 41.9 months) for those certified in 2010 (SD 7.8months); and 19.4 months (SD 7.4 months; minimum 2.6 months and maximum 29.9 months) for the cases certified in 2011.

Table 3.13 Time to compensation (in months) by year

Certification Year	Number	Time to compensation in months				
		Mean	95% CI	Std Deviation	Min	Max
2009	63	**37.8**	34.94-40.71	11.5	4	53.4
2010	23	**35.8**	32.43-39.19	7.8	1.6	41.9
2011	17	**19.4**	15.58-23.23	7.4	2.6	29.9
Total	103					

Table 3.14 Time to compensation from certification, by disease

Disease, Degree	Number compensated	Mean time to compensation in months (SD)	Minimum period (months)	Maximum period (months)
Asbestosis Interstitial 1st Degree	0			
Asbestos Pleural Disease and Interstitial 1st Degree	1	20.7		
Asbestosis Pleura and Interstitial 2nd Degree	2	45 (3.8)	43	48.4
Mesothelioma	2	43.2 (1.6)	42	44.3
Silicosis 1st Degree	98	34 (12.2)	1.6	53.4
Total	**103**	**34 (12.11)**	**1.6**	**53.4**

As can be seen from table 3.14, the mean months to compensation were greater for the second degree diseases than the first degree diseases.

3.5 The odds and risk factors for developing malignant mesothelioma from chrysotile asbestos mining: A case-control analysis

A total number of 882 cases and controls were used for the case-control analysis (cases=145; 733 controls). The cases were extracted from the MBOD dataset of certified compensable diseases and the controls were from the non compensable cases which were not used for analysis in the aforementioned objectives. The study included 145 cases (median age: 54 years; IQR 12; men 90%) and 733 controls (median age 59 years; IQR 14, men 91%)

The descriptive characteristics of the cases and controls are shown in table 3.15 below.The cases and controls were statistically significantly different with regards to age at claim in years, race, service max mine, and age group categories ($p < 0.05$) however they were not statistically different with regards to sex and worker status ($p > 0.05$).

Table 3.15 Summary of baseline characteristics of cases and controls

Characteristic	Cases n (%)	Controls n (%)	p-value*
Age at claim(years) median(IQR)	54 (12)	59 (14)	0.00
Age group (years)			0.00
40-49	24 (16.5)	237 (32.3)	
50-59	46 (31.7)	259 (35.3)	
60-69	42 (30.0)	150 (20.5)	
70+	20 (13.8)	44 (6.0)	
Unknown	13 (9.0)	43 (5.9)	
Total	145 (100.0)	733 (100.0)	
Latency (years)	33.5 (10.7)	30.0 (10.2)	0.0008
Latency categorical (years)			0.001
1-10	0 (0)	20 (2.7)	
11-20	16 (11)	82 (11.2)	
21-30	44 30.3	322 (43.9)	
31-40	49 (33.8)	199 (27.1)	
41-50	25 (17.2)	86 (11.7)	
50+	11 (7.6)	24 (3.3)	
Total	145 (100.0)	733 (100.0)	
Population group			0.00
Asian	2 (1.4)	2 (0.3)	
Black	93 (64.1)	650 (88.7)	
Coloured	5 (3.4)	2 (0.3)	
White	34 (23.4)	26 (3.5)	
Missing	11 (7.6)	53 (7.2)	
Total	145 (100.0)	733 (100.0)	
Service Max Mine duration (years)	141.1 (117.1)	166.6 (123.7)	0.0158
Service Max Mine duration(group-yrs)			0.018
0-4	54 (37.2)	175 (23.8)	
5-9	18 (12.4)	131 (17.9)	
10-14	19 (13.0)	133 (18.1)	
15-19	21 (14.5)	94 (12.8)	
20-24	18 (12.4)	82 (11.2)	
25-29	7 (4.8)	57 (7.8)	
30+	8 (5.5)	61 (8.3)	
Total	145 (100.0)	733 (100.0)	
Fibre type (Service Max mine)			0.00
No asbestos	83 (57.2)	554(75.6)	
Mpumalanga Chrysotile	5 (3.4)	17 (2.3)	
Amosite (Penge)	13 (9.0)	76 (10.4)	
Cape Crocidolite	20 (13.8)	33(4.5)	
Northern Province Amosite-chrysotile	23 (15.9)	51(7.0)	
Unknown asbestos mine	1 (0.7)	2 (0.3)	
Total	145 (100.0)	733 (100.0)	
Sex			0.66
Women	9 (6.2)	53 (7.2)	
Men	131 (90.3)	666 (90.9)	
Unknown	5 (3.4)	14 (1.9)	
Total	145 (100.0)	733 (100.0)	
Worker Status type			0.576
Active mine worker	28 (19.3)	147 (20.1)	
Ex-mineworker	115 (79.3)	572 (78.0)	
Unknown	2(1.4)	14 (1.9)	
Total	145 (100.0)	733 (100.0)	

***Ranksum test for latency and duration (continuous variables, not normally distributed**).

Mesothelioma risk factors

The results of risk factors associated with mesothelioma are presented in Table 3.16 below. Unconditional logistic regression revealed in univariate analysis that **age group**50-59 (60-69 and 70 years and above), had an increased significant risk of mesothelioma: OR (age group 50-59) =1.8 (95% CI 1.03-3.0; p<0.05); OR 2.8 (95%CI 1.6-4.8 p<0.05) for the 60-69 age group and OR 4.5 (95% CI 2.2-8.8 p<0.05) for the age group 70 and above.

Latency groups31-40years, 41-50 years and 50 years and above were also significantly associated with increased risk for mesothelioma (OR= 1.8; 95% CI 1.2-2.8: p<0.05; OR= 2.1 95% CI 1.2-3.6 p<0.05; OR=3.3 95% CI 1.5-7.3 p<0.05). Compared to the reference group (21-30years) of latency, those who had latency of 31-40 years were 1.8 times more likely to have mesothelioma; those who had 41-50 years since first exposure were 2.1 times more likely to have mesothelioma and those who had more than latency of more than 50 years were 3.3 times more likely to have mesothelioma.

Fiber type: Occupational mining exposure in Cape crocidolite mines and amosite/ Transvaal crocidolite had four times the odds and three times the odds of developing mesothelioma respectively, compared to occupational mining exposure to non-asbestos minerals or commodities with no asbestos. Chrysotile mining had two times more likely to have mesothelioma compared to reference group of no asbestos mining, however this was not statistically significant [OR:2; 95% CI (0.7-5.4) p>0.05].

Multivariate analysis

Multivariate analysis showed that, adjusted for age, gender and latency group; working in an asbestos mine namely crocidolite[adjusted OR=4.0 p<0.001 95% CI (2.0-8, 3)] and amosite/crocidolite [adjusted OR=3.9 p<0.001 95% CI (2.2-7.2)] were significantly associated with the risk of mesothelioma.Latency group was included in the final model after the likelihood ratio test (lr-test) showed improvement in final model significantly after addition (p=0.015).

Although there was no statistically significant association between chrysotile mining and mesothelioma, from univariate analysis [OR=2.0; p>0.05; 95% CI (0.7-5.4)], chrysotile mining was still used and forced into a model with risk factors identified for crocidolite and amosite/crocidolite namely latency, age and gender. In the final model, chrysotile mining had

1.5 times more odds of having mesothelioma compared to the reference group, however this was not statistically significant [OR=1.5; p>0.05; 95% CI (0.4-5.2)].

Table 3.16 Univariate and multivariate analysis of risk factors

Variable	**Univariate (Unadjusted)**			**Multivariate (Adjusted)**		
	OR	**95% CI**	p-value	OR	95% CI	p-value
Age-group						
40-49 (ref)	**1**			1		
50-59	**1.8**	**1.03- 3.0**	0.0036	**1.7**	**1.01-3.0**	**0.044**
60-69	**2.8**	**1.6- 4.8**	0.000	**2.7**	**1.5 -5.4**	**0.000**
70+	**4.5**	**2.2-8.8**	0.000	**3.9**	**1.8-8.1**	**0.000**
Fiber type (asbestos)						
No asbestos (ref)	**1**			1		
Mpumalanga Chrysotile	**2.0**	**0.7 – 5.4**	0.196	1.5	0.4 -5.2	0.580
Amosite (Penge)	**1.1**	**0.6-2.1**	0.681	1.3	0.6 – 2.8	0.430
Cape Crocidolite	**4.0**	**2.2 – 7.4**	0.000	**4.0**	**2.0 – 8.3**	**0.000**
Northern Province Amosite- Crocidolite	**3.0**	**1.7 -5.1**	0.000	**3.9**	**2.2 – 7.2**	**0.000**
Unknown asbestos mine	**3.3**	**0.3 –37.2**	0.327	2.9	0.2 -37.8	0.405
Latency group						
21-30 (ref)	**1**			1		
1-10	**-**	**-**	-	-		
11-20	**1.4**	**0.8 -2.7**	0.261	0.6	0.3 – 1.1	0.115
31-40	**1.8**	**1.2 -2.8**	0.009	0.8	0.4 -1.6	0.483
41-50	**2.1**	**1.2- 3.6**	0.007	0.6	0.2 -1.3	0.196
50+	**3.3**	**1.5- 7.3**	0.002	0.7	0.2 -2.3	0.579
Population group						
Asian (ref)	**1**					
Black	0.1	0.02-1.0	0.53			
Colored	2.5	0.2 - 32.1	0.48			
White	1.3	0.2 - 9.9	0.80			
Sex						
Women (ref)	**1**			1		
Men	1.2	0.6 – 2.4	0.694	**2.4**	**1.1- 5.9**	**0.035**
Service duration (yrs)	0.9	0.8 -0.9	0.19			
Service duration categories (years)						
0-4 (ref)	**1**					
5-9	3.5	0.3 -36.8	0.30			
10-14	3.2	0.4 -29.1	0.30			
15-19	0.9	0.4-16.7	0.93			
20-24	0.9	0.1 -9.1	0.91			
25-29	3.8	0.4 -38.8	0.23			
30+	1.2	0.2 -10.2	0.84			
Worker Status type						
Active	**1**					
Ex-mineworker	**0.9**	**0.6 -1.5**	**0.877**			

CHAPTER FOUR- DISCUSSION

Compensable occupational lung diseases in South Africa 2004-2012

There is a large burden of occupational lung disease in South African current and ex-miners. Of the active living miners who were employed in SA between 2004 and 2012, 49 179were diagnosed with occupational lung disease of more than 10% impairment.

Mining status was a major determinant of compensable occupational lung disease in this study as shown by a significant proportion of disease, 73% (n=49 179) being in current miners, almost 25% (n=16 805)in former miners.The current miners seemed to have a greater disease burden compared to ex-miners. This could be partly due to the high number of living current miners during this period (17) compared to the estimated two million ex-miners in South Africa, Lesotho, Mozambique and Swaziland(18), but also because current miners access the compensation system better than the former miners.

Another reason could be due to ease of access and submission for compensation by employer compared to the passive method dependent on the individual ex-miner to attend two-yearly BME. Other contributing factors to the lower number of ex- miners vs. current miners, include possibly, a higher number of ex-workers who died following leaving work for many reasons including the possibility of having occupational lung diseases and poor access to health care compared to when they are in employment. The latter is explained in the literature by the extent to which ex-miners return to labour sending areas from other countries as well as South African rural areas(92,93). In one study, ex-miners had not received medical examination (BME) on leaving the mine and they did not know of the compensation benefits (87).

It is also likely that ex-miners might have left employment because of ill health; more than 40% impairment thus certified as second degree and no further compensation to be awarded. This could possibly explain ongoing benefit medical examination but no longer certifiable with compensable disease, thus eliminated at early stages of the process because of having reached a ceiling for compensation.

The occupational lung diseases that contributed significantly to the total number of compensable diseases during the period under study were tuberculosis (61%), silicosis (15%)

asbestos pleural disease and interstitial asbestosis (12%). These findings are in line with what is already known with regards to the burden of tuberculosis in the mining sector (20,52,55,94).

Tuberculosis

Considering that TB is compensable for loss of earnings (TB current, can antedate and reactivated) as well for residual impairment 12 months after completion of treatment, this does produce a major contribution to compensation numbers being from or closely related to the current mining status. Compensation for loss of earnings is directly related to current employment, and TB diagnosed during employment, thus reported immediately following confirmation of diagnosis. However first and second degree awards are actually based on an extended follow up beyond the treatment period. This requires a follow up of lung function tests and radiological imaging after 12 months of completion of treatment, which might be challenging but should be incorporated into an active scheduling system. This could be a policy consideration especially for former mine workers to undergo medical assessment after twelve months following TB treatment, and incorporation of this in the current public health system, to actively schedule or follow up these cases from the centres where treatment was received. In service miners, do enjoy this benefit as they have access and are part of annual medical surveillance program, which could also coincide with assessment after twelve months of completion.

Although studies have calculated the actual contribution to the South African population's prevalence (18), this could not be meaningfully done as compensable tuberculosis can include cases other than cases diagnosed during that year, for example T can antedate, first and second degree which are residual impairments twelve months after treatment completion. The same principle could be applied to TB cases diagnosed and contributing to the burden of TB but not being compensable because of the status being NCD, TB as before or TB cannot antedate.

The highest number of successful claims was TB and TB with other disease. This was predominantly due to claimants whose maximal employment had been in gold mining, but was also prevalent in other commodities. This was expected considering the high number of gold miners as well as former gold miners working in other commodities, like platinum mining. The preponderance for gold, from an occupational health perspective is due to known exposure to crystalline silica dust. It is known that HIV drove an increase in TB rates as well as mortality rates from the mid 1990 to mid 2000, with a decline over the past decade probably due to antiretroviral therapy.

Gold mining was the commodity with highest contribution to the TB burden, probably because of the silica dust levels, and changing employment patterns from shorter employment contracts to longer permanent employment, thus increasing cumulative exposure (28,32,93,95). The finding of tuberculosis in platinum mining, as the second commodity contributing to the burden of tuberculosis in mining, could be explained by changing employment patterns following the shrinking gold mining and growing platinum mining sectors (13,17). However another explanation for the high levels of tuberculosis from other commodities could include the high background in mining populations because of other non-occupational factors namely, migration and high prevalence of HIV infection (28,55,93).

Although the burden is large, it could be seen as an output of a strengthened tuberculosis management programme including intensified case finding. From this perspective, the secondary prevention aspect could be seen as being functional, although this would require a separate in-depth impact assessment for the intensified TB management programme, as reported by the Chamber of Mines (37), and reporting patterns by the medical practitioners in the mining industry.

Silicosis

Silicosis certifications during this period contributed 15% (n=9894) to the total certifications of compensable occupational lung disease; attributable to high silica dust levels in the past. Considering that the latent period of exposure and manifestation of abnormality is at least 5years for silicosis and typically more than or equal to 15years for PMF, the findings of a high proportion of silicosis can be explained by exposure levels that had not changed in the 1990'sas per findings of the Leon Commission (25,78). The OEL for silica dusthad not been lowered from the 0.1 mg/m^3 despite discussions that started in the 2000's on lowering the OEL (52). It should be noted that, even if the OEL had been lowered, the suggested level was 0.05mg/m^{3}might have not been sufficiently protective to avert disease (78). The reduction might have had an impact on lowering the incidence among recruits that were new at that time.

A significant observation from this data is the high proportion of silicosis cases with less than 15years of exposure. There was no evidence to suggest that this could be attributed to the recent exceedance of 0.1 mg/m3 have been high enough to produce a large burden of accelerated silicosis. However, a plausible explanation is that of TB disease being an effect modifier, as this can produce nodules and fibrotic masses in much shorter periods. Another important consideration should be that certification of silicosis in life is based on radiological silicosis, which does not include the true presence of disease as in sub-radiological disease for example in autopsy cases.

The finding that none of the platinum miners diagnosed with silicosis had been exclusively employed in the platinum mines could be an indication of low silica dust content of platinum ore. If any accidental exposure to silica dust exists, it could be low enough to be below risk of development of silicosis. It should be noted though that the absence is of compensable silicosis, not silicosis per se. Silicosis without lung function impairment would be NCD and thus missed, which may explain the discordance between the findings of this study and those of Nelson and Murray (2013) which detected silicosis in exclusively platinum miners at autopsy (42). In the same study, after exclusion of possible exposure to silica dust in gold mining, five miners had silicosis and 25 had fibrotic nodules in the nodesat autopsy (42).

However the finding of silicosis in platinum miners was not surprising, considering the rise in employment numbers of platinum mining. This is thus, explained by movement of former gold miners into platinum employment. This rise also coincides with a decline in employment numbers in the gold mining commodity from 2005, as illustrated in Table 1.2.

There was very little statistical power to find a difference between anthracite and bituminous coal mining with regards to coal workers' pneumoconiosis. This was mainly because of the small anthracite group.

The compensable occupational lung diseases in this study were predominantly in the 40-49 years group, male active mine workers and from the black population group. These characteristics are the same as defined in studies conducted on occupational lung diseases in the mining from both current miners' studies (32) mainly and the ex-miners' studies (79).

Asbestos related diseases

Other diseases that contributed to the burden include the asbestos related diseases, which were at least 13% (n=8665) of the compensable occupational lung diseases. Although this is lesser than silicosis, with more recent exposures, it confirms that the legacy of asbestos mining has remained with South Africa. Although the true burden of asbestos related diseases is not known, considering that the last asbestos mine closed in 2002 and the long latency of asbestos related diseases (30-40years), a lot more should be expected to surface considering the numbers exposed in the 1970's, almost forty years ago (52,62,75).

The number of asbestosis (interstitial) cases is high; however, the amount of asbestos related disease in this subset is high but in line with long latency for asbestos related diseases. It has been argued that asbestos related pleural disease and mesothelioma can occur following low levels of exposure, specifically environmental contamination in the form of domestic or neighborhood exposure (61).

Of note with the asbestos related diseases, is the high proportion of women in the disease burden, being the only disease groups including pneumoconiosis with a high proportion of women. The burden of disease in women from asbestos mining is high, and is aligned with large numbers of proportional exposed for women in this commodity before it closed down (84).

Davies *et.al*. (2001) reported a large burden of asbestos related disease in women when they conducted a survey in the Mafefe area in 1996 (84). They attributed this to a number of issues, namely the nature of duties performed, possible domestic exposure and other occupational exposures being from working in miners accommodation areas as well as possibly from environmental contamination.

Three ex-miners were certified with mesothelioma during the 2004-2012 period, based on the database, with exclusive diamond mining. However, careful review of records showed that only two could be described as exclusively exposed in diamond mining. One of the three cases had worked for a significant period in the diamond mining, with last exposure in a gold mine, but he had had exposure in an asbestos mine in his earlier employment years. Based on the information available two cases diagnosed with mesothelioma had exclusive diamond mining. This highlights the importance of accurate documentation and good quality of service records, for a disease of this public health importance to be attributed to a commodity.

Time to Compensation

The low proportions had been compensated for each year in this study, and the time to compensation was unacceptably long, particularly in those with serious diseases. A mean time of approximately three years for first-degree diseases is bothersome, however the same period for second degree diseases is even more concerning that second degree is equivalent to more than 40% impairment. This implies that a miner certified with mesothelioma has almost no chance of benefiting personally from ODMWA, as seen in Table 3.14.

Malignant mesothelioma and chrysotile fibre

The case control study was conducted to attempt to improve insight on the relationship between malignant mesothelioma development and exclusive chrysotile mining occupational exposure, and if so what other determinants and risk factors could be there. This was an opportunity given that the database had information collected for more than ten years, with a large number of cases of malignant mesothelioma, given the relative rarity of this tumor, compared to other compensable malignancies in the mining occupational setting.

The case control study showed increased odds ratios for crocidolite(4.0, 95% CI: 2.0-8.3; $p<0.05$)and amosite crocidolite mixed fibres (OR=3.9, 95% CI: 2.2-7.2, $p< 0.05$) from the Northern Transvaal, and no significantly increased risk was found for the chrysotile (OR= 1.5, 95% CI: 0.4-5.2, $p> 0.05$) or amosite fibers (OR=1.3, 95% CI: 0.6-2.8, $p>0.05$). This is in line with what has been reported in studies with regards to mesotheliogenic gradient among fiber groups namely crocidolite>amosite> chrysotile. In this study a new category of the mixed fiber was included which in other studies is referred to as Transvaal crocidolite and/ or lumped with the Cape crocidolite (73,74).

The low number of mesothelioma cases from chrysotile mining, in this study might not only be a due to carcinogenic fibre properties but also because the number of employees in the that the chrysotile mining and milling (near Msauli- Eastern Transvaal- Barberton area) was significantly less than employees in employed in companies with other two fiber types(73).

However in this study, five (3.4 %) of mesothelioma cases were from chrysotile mining, based on linkage of exposure mine and fiber type. It should be noted however that occupational exposure history is captured according to what is presented by employees. It should also be noted that, as indicated by Felix in her PhD thesis(63), mines that were shared by a similar employer had practices where senior experienced personnel would visit the sister mines for the purpose of skills transfer, and later return to their original employment mines. It is therefore likely that these mesothelioma cases could have arisen from those brief exposures, considering the amount and duration of exposure required for mesothelioma to develop (62).

This argument is however, compounded by the findings of a case control analysis conducted to determine the risk factors associated with mesothelioma development in chrysotile miners.

No mesothelioma has been reported from exclusive chrysotile miners in SA; however, the author suggested that in his research, this might be due to lower numbers of workers in chrysotile mines in the Barberton area compared to the numbers employed elsewhere (73).

Other reports (64,65,71,96) suggest the bio-persistence properties of the crocidolite and amosite fibers versus clearance of chrysotile fibers, thus not associated with long latency periods, associated with development of mesothelioma. In this case control analysis, chrysotile fiber type was not a risk factor for mesothelioma and no model could be constructed to this effect. The findings from the case control analysis therefore, are in line with previous reports that in South Africa, no study has confirmed the risk of mesothelioma from chrysotile mining (62), but possible environmental exposure to other fiber types (61), contamination of chrysotile fiber by tremolite (74) as well as studies from mixed environmental, spurious and occupational exposure (73), could possibly explain the cases found in this study even though there was no statistically significant risk.

Similar to other studies conducted in South African population (73,97) the majority of risk is within the crocidolite fibre type. All cases and controls had some exposure to mining hazards; however there was no accurate documentation of occupational asbestos exposure. The strength of this study is that both cases and controls were sourced from the same database, where all miners and ex-miners have equal chance of being submitted to the MBOD for compensation, depending on the medical practitioner assessing and completing forms.

The reader should bear in mind that the changes seen in disease numbers could be due to factors external to the risks directly related to exposure in mines. For example TB changes in numbers could be due to HIV, and a rapid rise in asbestos related diseases could be due to the activity of the Asbestos and Kgalagadi Relief Trusts. The two trusts from 2004 set up active surveillance for asbestos related diseases, to provide compensation to people who contracted asbestos related diseaase4s as a result of past mining of asbestos in rural areas of South Africa. This resulted in surge of asbestos related disease over a period, thus resulting in bias qualifying mines possibly regionally. The amount of disease claims in women could also be attributed to the trusts.

Limitations of the study

This study has a number of limitations. Importantly being secondary data analysis, information was collected for another purpose, namely compensation. Information collected therefore, would primarily be suited for compensation and requirements thereof. Incomplete records on the data base could have reduced the true burden of compensable disease attributable to specific exposure in a commodity.

The number of certifications by year and the apparent trends are likely to be artifacts of the Certification Committee rather than a function of actual disease prevalence. For example, efforts were made in 2007 and 2008 to reduce the backlog of claims awaiting adjudication, hence the spike in numbers certified. The overall picture over the years of the study is nevertheless informative; South Africa still has very large numbers of current and former miners with occupational lung disease.

Misclassification of exposure could occur by the assignment of maximum service workplace as the workplace to which disease is attributed. The mine where maximum service was held was recorded as other in the database, which could mean the mine was not known or was not documented during submission.

Another example of misclassification of exposure is the lack of accurate documentation of asbestos mine, and hence fibre type, for the case control analysis. Also, the true latency estimation, to the onset of asbestos exposure only to an asbestos mine, although other occupations in non-asbestos mining or non-mining environment are known to be at risk of asbestos exposure. The absence of residential information is problematic as mesothelioma could have arisen from environmental exposure.

One other limitation of this study was absence of residential exposure information for both cases and controls and no occupational exposure details for controls other than mine worked at. The disease claimed for was also not included for controls, which could have resulted in selection bias as some of the cases could have had mesothelioma but certified NCD because of no complete diagnostic workup details. It is also possible that a small number of controlswith asbestos related cancer, e.g laryngeal cancer, were certified with NCD.

Recruitment of cases from MBOD MWC database may have introduced selection bias, as some cases may have not had adequate documents pertaining to diagnosis at the time of submission, thus certified as not compensable, ending up being controls in this study. The cases were not statistically different with regards demographic characteristics, and these were not considered to be significant confounders or effect modifiers. The cases used from the database may not necessarily be incidence cases, but prevalence as they will have been diagnosed and forwarded for compensation, and it may have taken a while to submit proof of diagnosis and thus be not compensable.However it is also likely that cases would have been seen and diagnosed at the respiratory and oncology clinics, and submitted for compensation with all relevant requirements compared to controls not submitted with complete clinical details.

Recall bias is unlikely to have affected this study, as there should be no differential recall for either cases or controls, considering that compensation forms are completed by medical practitioners when assessing patients before submission for compensation. This would apply similarly for cases and controls, and also further rendered unlikely by the presence of an occupational history requested at submission and for compensation.

Occupational or labour history is provided byThe Employment Bureau of Africa(TEBA) or objective evidence of employment is submitted with claim submission where no TEBA form is available. Although a number of risk factors or mesothelioma determinants for this study were assessed, asbestos dust exposure is the only significant causal factor for mesothelioma. This is well known to medical service providers. It is unlikely that the ability to accurately recall past work schedules would be related to case/control status.

Conclusion and recommendations

This study found a large burden of occupational lung diseases in living South African active and ex-miners, certified between 2004 and 2012. This burden consists mainly of tuberculosis from the loss of earnings mainly but also the whole person impairment resulting from tuberculosis namely first and second degree tuberculosis. A significant finding from this study was the significant proportion of miners certified with pneumoconiosis with less than fifteen years of mining service, and specifically the number of silicosis certifications with mining service of less than ten years.

There was also a substantial number of cases of tuberculosis, mainly in living current miners, and mostly of the first degree. This was a significant finding considering the interventions in the mining sector through health programmes namely, antiretroviral treatment implementation on 2002, intensified TB management programmes and interventions on socio economic determinants. This study does not however attempt to replace a post- intervention study on the impact of these programmes.

Some of the findings from this study could not provide with certainty new information required to update the body of knowledge on occupational lung diseases, considering the amount of missing data and incomplete information on service records. For example, the finding of no silicosis certification in life from miners with exclusive platinum mining, the burden of disease in coal miners with regards to coal type and rank, are some of the issues that could be further looked into.

The burden of asbestos related disease in women contributed to the number of women certified during this period, even though asbestos is no longer mined in South Africa. A far lesser number of women were certified with disease from other commodities.

The findings from this study support some of the findings from other studies with regards to no established risk for mesothelioma from exclusive chrysotile mining; unacceptably long time to compensation and the incomplete documentation of exposure history in the form of service records. Further in depth analysis will require to be conducted for the five mesothelioma cases with exclusive chrysotile mining.

It is recommended that accurate meaningful exposure history is recorded for accurate attribution of diseases to specific commodities. This will also enable early detection of newer issues and trends of relevance to the occupational health field, from a South African perspective.

The fewer number of claims and certification of ex-miners should be attended to through better access to the benefit medical examinations and improvement in submission from various decentralized centres with assistance of adequately trained human resource personnel.

Another recommendation will be a careful undertaking to attend to reducing the unacceptably long time to compensation, and assessment of time of certification which was not covered in this study. The former could be done by developing a separate mechanism of handling, certification and compensation of the tuberculosis cases diagnosed and submitted during service, which form a significant majority. These should not hamper the compensation process for the other diseases, certification and compensation of the former miners and the cancers requiring more urgent attention and with a shorter life expectancy from diagnosis.

Finally, the amount of compensable disease certified in living miners and ex-miners as found in this study could be an indication of efficiency of the certification committee, handling of backlog rather than the true extent of disease in this population in South Africa.

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APPENDICES

Appendix One:Plagiarism declaration report

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I N·A NDABA (Student number: 561521) am a student registered for the degree of MMED (OCCUPATIONAL MEDICINE) in the academic year _______.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.

Signature: ________ Date: 2016/08/12

26/04/2015
1

Appendix Two: Ethics approval from the University ofWitwatersrand, Health Sciences Research Ethics Committee

R14/49 Dr Nompumelelo Ndaba

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130931

NAME: (Principal Investigator)	Dr Nompumelelo Ndaba
DEPARTMENT:	Occupational Health National Institute of Occupational Health
PROJECT TITLE:	Compensable Occupational Lung Diseases in Living Miners and Ex-miners in South Africa, 2003-2013
DATE CONSIDERED:	27/09/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof David Rees
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	25/10/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**

Principal Investigator Signature ____________ Date ____________

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix Three: Approval letter from Department of Health to use compensation data

health

Department:
Health
REPUBLIC OF SOUTH AFRICA

COMPENSATION COMMISSIONER
FOR OCCUPATIONAL DISEASES (CCOD)
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01 July 2013

To whom it may concern

Re: Dr Nompumelelo Ndaba: Research project 'Compensable occupational lung diseases in living miners and ex-miners in South Africa, 2003-2012'

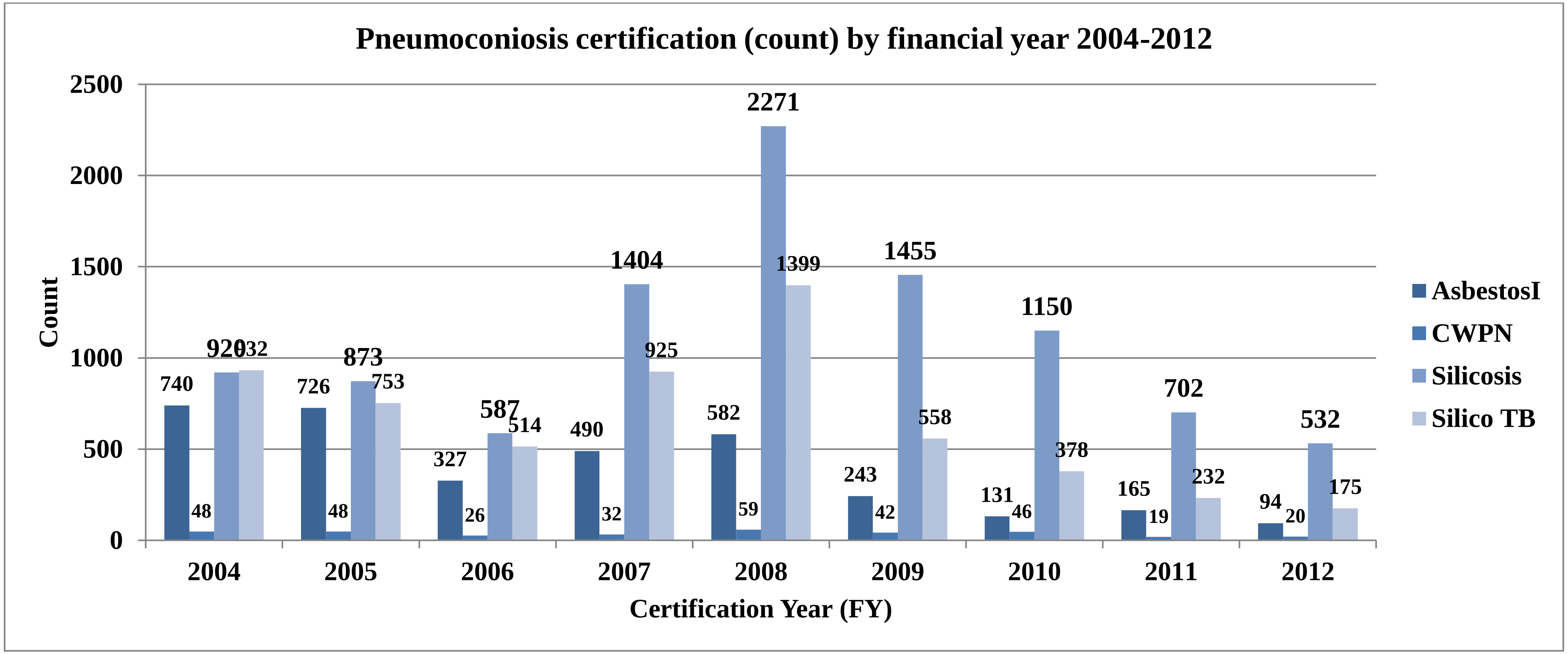
This letter is a confirmation that Dr NA Ndaba will be given access to the data from the Medical Bureau for Occupational Diseases (MBOD) and the Compensation Commission for Occupational Diseases (CCOD) datasets for analysis for this research project. Note that Ethics approval will be needed and that all data is confidential with the final report having no identified individuals.

The research will assist with some of the management interventions being undertaken at the MBOD and CCOD and we await the research findings.

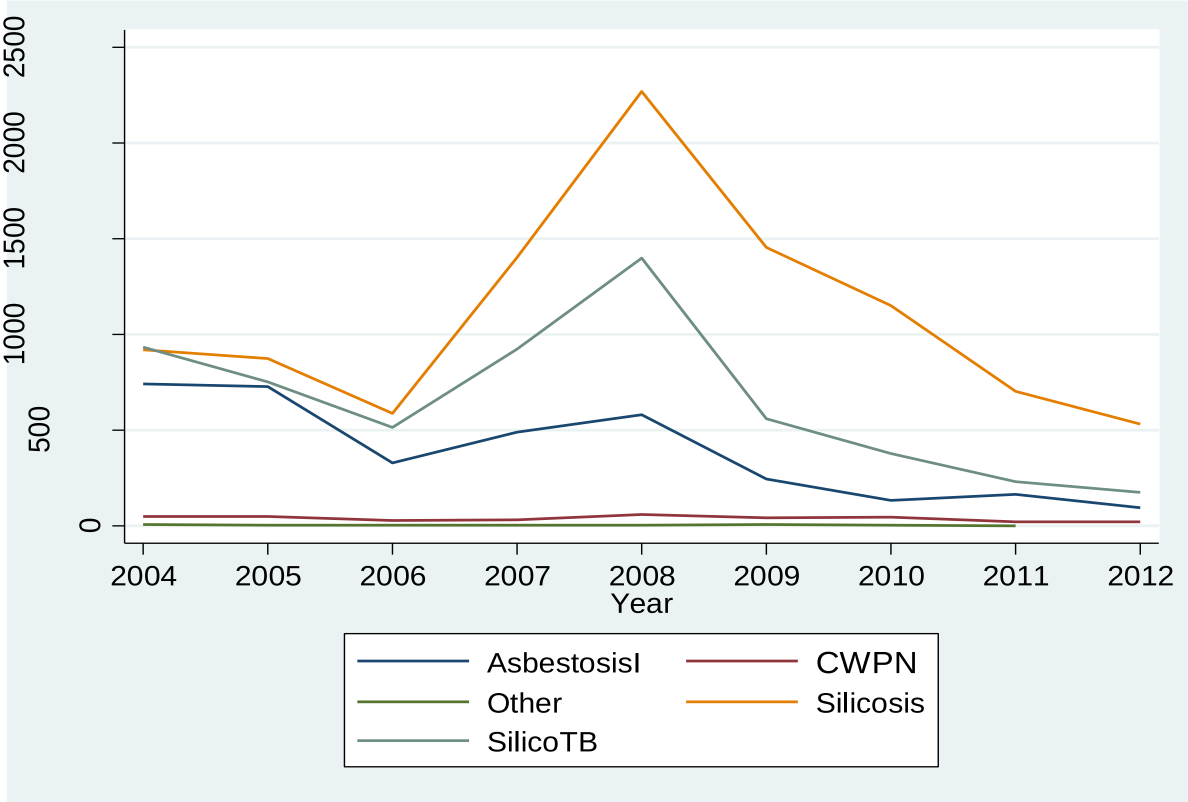
Yours sincerely

Dr Barry Kistnasamy
Compensation Commissioner

Appendix Four: Pneumoconiosis certification trend showing count by financial year



Appendix Five: Pneumoconiosis certification trend illustration with no numbers



Appendix Six: Summary of coal type and Rank designation by province and region

Province	Coal type	Rank Designation	Region
Mpumalanga	Bituminous	Medium Rank C	Witbank-Middelburg-Secunda
	Bituminous	Medium Rank C	Belfast-Carolina-Ermelo
	Bituminous	Medium Rank C	Piet Retief- Wakkerstroom
	Semi-Anthracites and Anthracites	High Rank C	Kangwane (Komatipoort)
Northern Province	Bituminous	Medium Rank C	Elisras
	Bituminous	Medium Rank B	Venda
Free State	Bituminous	Medium Rank D	Sasolburg
KwaZulu-Natal	Semi-Anthracites and Anthracites		Dundee-Newcastle-Utrecht
	Bituminous	Medium Rank C	Welgedacht
	Semi-Anthracites and Anthracites	High Rank B/C	Vryheid
	Semi-Anthracites and Anthracites	High-Rank B	Ulundi

Adapted from Operating and developing coal mines in the republic of South Africa, 2004

Appendix Seven: Mine names and conversion in line with fibre type

0: non-asbestos mine **1: Chrysotile mine (Mpumalanga)**

2: Amosite mine (Penge) **3: Cape Croccidolite mine**

4: Amosite and Croccidolite (NorthernProvince/Limpopo) 5: Unknown asbestos mine

MINE_NAME	Fiber type
Gold, manganese, coal, platinum, chrome , diamond	**0**
African Chrysotile Asb Ltd	**1**
Bewaarskloof Mine	**3**
Bretby Asbestos Mine	**3**
Bute Mine Heuningvlei	**1**
Cape Blue Mine Pty Ltd	**3**
Cork Asbestos Mining	**4**
Danielskuil Cape Blue Asbestos	**3**
Danielskuil Cape Blue(Noordhoek)	**3**
Dublin Cons Asbestos Mines (Tubex)	**3**
Egnep Pty Ltd (Malipsdrif)**	**2**
Egnep Pty Ltd (Penge)**	**2**
Gefco (Coretsi)	**4**
Gefco (RiriesAsb Mine)	**4**
Gemini (Asbestos)	**4**
Griqualand &EmmerentiaAsb Pty Ltd	**1**
Griqualand Chrysoltile Mines (Bute Mine)	**1**
Kaapsehoop Asbestos Pty Ltd	**3**
Kalkkloof Asbestos Mines	**1**
Koegas Asbestos Mine	**3**
Krommelboog [Taung]	**3**
Kuruman Cape Blue Asb (Corheim)	**3**
Kuruman Cape Blue Asb (Kuruman East)	**3**
Penge Asbestos Mine**	**2**
Pomfret Asbestos Mine	**3**
Unknown Asbestos Mine	**5**
WandragAsb Pty Ltd	**3**
Missing	**5**

**Amosite mines in the Penge area namely, Penge group of mines (Penge, Weltervred and Krommellenboog); Cape asbestos (Cape plc) operation Malipsdrift (Egnep) and Dublin Consolidated mines.

Appendix Eight: Mine name, allocated number of cases and controls and fiber type

Mine Name	Number of cases and controls	Fibre type
Gold, manganese, coal, platinum, chrome, diamond	639	0
African Chrysotile Asb Ltd	8	1
Bewaarskloof Mine	4	3
Bretby Asbestos Mine	1	3
Bute Mine Heuningvlei	1	1
Cape Blue Mine Pty Ltd	5	3
Cork Asbestos Mining	1	4
Danielskuil Cape Blue Asbestos	3	3
Danielskuil Cape Blue(Noordhoek)	1	3
Dublin Cons Asbestos Mines (Tubex)	1	3
Egnep Pty Ltd (Malipsdrif)	2	2
Egnep Pty Ltd (Penge)	3	2
Gefco (Coretsi)	53	4
Gefco (RiriesAsb Mine)	19	4
Gemini (Asbestos)	1	4
Griqualand &EmmerentiaAsb Pty Ltd	9	1
Griqualand Chrysoltile Mines (Bute Mine	3	1
Kaapsehoop Asbestos Pty Ltd	1	3
Kalkkloof Asbestos Mines	1	1
Koegas Asbestos Mine	7	3
Krommelboog [Taung]	2	3
Kuruman Cape Blue Asb (Corheim)	5	3
Kuruman Cape Blue Asb (Kuruman East)	8	3
Penge Asbestos Mine	84	2
Pomfret Asbestos Mine	12	3
Unknown Asbestos Mine	3	5
WandragAsb Pty Ltd	3	3
Missing	2	5
Total	880	

Appendix Nine: Diseases compensated from the selected sample by year of certification

Certification year	Disease Degree				
	ASBM2	ASBPI1	ASBPI2	SIL1	Total
2009	2	1	2	58	63
2010	0	0	0	23	23
2011	0	0	0	17	17
Total	2	1	2	98	103

Appendix Ten: Total claims submitted per year, by claim status of the claimant (living and deceased) 2004/05-2012/13

Year	Living		Deceased		Deceased, no organs removed		Total Claims
	n	%	n	%	n	%	
2004/05	21 453	90.2	2 082	8.8	257	1.1	23 792
2005/06	16 845	88.0	1 958	10.2	331	1.7	19 134
2006/07	14 949	88.9	1 761	10.5	107	0.6	16 817
2007/08	13 109	88.8	1 628	11.0	27	0.2	14 764
2008/09	11 307	86.0	1 837	14.0	4	0.0	13 148
2009/10	10 542	86.9	1 585	13.1	2	0.0	12 129
2010/11	10 194	86.9	1 534	13.1	1	0.0	11 729
2011/12	8 633	87.1	1 277	12.9	3	0.0	9 913
2012/13	7 245	87.3	1 054	12.7	1	0.0	8 300
Total	**114 277**	**88.1**	**14 716**	**11.3**	**733**	**0.6**	**129 726**

Appendix Eleven: Total claims submitted, certifications and certification outcomes per year, 2004/05-2012/13

Year	Total Claims	Certified all	NCD		Other*		Compensable all		Compensable deceased and deceased with no organs		Compensable living	
			n	%	n	%	n	%	n	%	n	%
2004/05	23 792	20 635	8 374	40.6	895	4.3	11 366	55.1	1980	17.4	9386	82.6
2005/06	19 134	17 831	7 489	44	541	3.0	9801	55	1879	19.2	7922	80.8
2006/07	16 817	10 292	4 440	43	215	2.1	5637	54.8	974	17.3	4663	82.7
2007/08	14 764	19 397	8 068	41.6	271	1.4	11 058	57	1 455	13.2	9603	86.8
2008/09	13 148	27 704	11 874	42.9	597	2.2	15 233	55	1 746	11.5	13487	88.5
2009/10	12 129	17 209	6 387	37	987	5.7	9835	57.2	1 870	19	7965	81
2010/11	11 729	12 012	4 343	36.2	418	3.5	7251	60.4	1 381	19	5870	81
2011/12	9 913	10 768	3 923	36.4	272	2.5	6573	61	1 285	19.5	5288	80.5
2012/13	8 300	8 203	3 475	42.4	181	2.2	4547	55.4	1 071	23.6	3476	76.4
Total	**129 726**	**144 051**	**58 373**	**40.5**	**4377**	**3.0**	**81 301**	**56.4**	**13 641**	**16.8**	**67 660**	**83.2**

* Other= defer, appeals. NCD= NCD, T cannot antedate and TB not from risk work. Claims submitted per year are not necessarily certified in that year as some cases may be submitted with incomplete documents or deferred because of reasons and decisions of the certification committee.